X.

Contributions to the Natural History of the ACALEPHÆ *of North America.*

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PART II. — *On the Beroid Medusæ of the Shores of Massachusetts, in their Perfect State of Development.*

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PLEUROBRACHIA.

THE character of the Beroid Medusæ is entirely different from that of the Discophoræ. Both their form and organs of locomotion give them a different appearance. The common Discoid Medusæ, setting aside the various modifications arising from marked peculiarities of their outline, move like an umbrella, which, alternately opening and shutting, would make its way under water by means of such movements. It is by contraction of the body itself, — of its mass, or rather of the muscles which pervade that mass, — that motion is produced in those animals. Not so in the Beroid Medusæ, where the whole body, more or less spherical or ovate, compact or split at one end, is kept swimming by the flapping of innumerable small oars, arranged in vertical rows, like the ribs of an orange, upon the outer surface, along which horizontal combs of little fringes move with extraordinary rapidity, forming a sort of revolving wheel. These rows are generally eight in number, extending from one point to the opposite side, like the meridians of an artificial globe. But owing to the inequalities in the motions of their vertical flappers, and their almost circular arrangement around the more or less spherical body, these animals have a somewhat rotatory motion, unless the oars move on all sides with perfect steadiness and uniformity.

There can be scarcely any thing more beautiful to behold, than such a living transparent sphere sailing through the water, running one way or another, now slowly revolving upon itself, then assuming a straight course, or retrograding, advancing, and moving sideways in all directions with equal precision and rapidity, then stopping to pause, for

a time almost immovable, with a slight waving of some of its vibrating fringes, which gentle motion easily counterbalances the difference in specific gravity between these animals and the water in which they live. So Pleurobrachia may appear at times, and so it even does appear when it moves in its state of contraction. But generally, when active, it hangs out a pair of most remarkable appendages, the structure and length and contractility of which are equally surprising, and exceed, in wonderful adaptation, all I have ever known among animal structures. Two apparently simple irregular, unequal threads will hang out from two opposite points on the sides of the sphere. Presently they will elongate, equal in length the diameter of the sphere, presently surpass it, increase to two, three, five, ten, twenty times the diameter of the body, and more and more; so much so, that it would seem as if these threads had the power of endless extension and development. But as they lengthen, they appear more complicated. From one of their sides other delicate threads shoot out like fringes, forming a row of beards, like those of the most elegant ostrich feather, and each of these threads itself elongates till it equals in length the diameter of the whole body, and bends in the most graceful curves. These two long streamers, stretching out in straight or undulating lines, sometimes parallel, then diverging, follow the motions of the main sphere, being carried on with it in all its movements. Upon considering this wonderful being, one is at a loss which most to admire, the elegance and complication of that structure, or the delicacy of the colors and hues, which, with the freshness of the morning dew upon the rose, shine from its whole surface. Like a planet round its sun, or, more exactly, like the comet with its magic tail, our little animal moves in its element, as those larger bodies revolve in space, but unlike them, and to our admiration, it moves freely in all directions; and nothing can be more attractive than to watch such a little living comet, as it darts with its tail in undetermined ways, and revolves upon itself, unfolding and bending its appendages with equal ease and elegance, at times allowing them to float for their whole length, at times shortening them in quick contractions, and causing them to disappear suddenly, then dropping them, as it were, from its surface, so that they seem to fall entirely away, till, lengthened to the utmost, they again follow the direction of the body to which they are attached, and with which the connection that regulates their movements seems as mysterious as the changes are extraordinary and unexpected. For hours and hours I have sat before them and watched their movements, and have never been tired of admiring their graceful undulations. And though I have found contractile fibres in these thin threads, showing that these movements are of a muscular nature, it is still a unique fact in the organization of animal bodies, that by means of muscular action parts may be elongated and contracted

to such extraordinary and extensive limits. And what is so surprising is not so much the sudden powerful contraction which brings within the compact limits of a pin's head the whole mass of these tentacles, that a moment before were floating so elegantly through such a great extent in the water, as the relaxation, which takes place in an absolutely passive manner; for when watching them, we are suddenly struck with astonishment on finding that the tentacle which we expected to see drop to the bottom of the jar is still in organic connection with the body from which it hangs. Plate I. represents some few of the attitudes of Pleurobrachia in its various movements; but I cannot find words to describe all the beautiful changes which the parts thus in motion assume in different attitudes. At one moment, the threads, when contracted, seem nodose; next, when more elongated, these knots are stretched into the appearance of a spiral; next, the spiral, elongating, assumes the appearance of a straight or waving line. But it is especially in the successive appearances of the lateral fringes arising from the main thread, that the most extraordinary diversity is displayed. Not only are they stretched under all possible angles from the main stem, at times seeming perpendicular to it, or bent more or less in the same direction, and again as if combed into one mass; but a moment afterwards every thread seems to be curled or waving, the main thread being straight or undulating; then the shorter threads will be stretched straight for some distance, and then suddenly bent at various angles upon themselves, and perhaps repeat such zigzags several times, or they will be stretched in one direction, and bent at various angles in the plane of another direction; then they will be coiled up from the tip, and remain hanging like pearls suspended by a delicate thread to the main stem, or, like a broken whip, be bent in an acute angle upon themselves, with as stiff an appearance as if the whole were made up of wires; and, to complete the wonder, a part of the length of the main thread will assume one appearance, and another part another, and pass from one into the other in the quickest possible succession; so that I can truly say, I have not known in the animal kingdom an organism exhibiting more sudden changes, and presenting more diversified and beautiful images, the action, meanwhile, being produced in such a way as hardly to be understood. For when expanded, these threads resemble rather a delicate fabric spun with the finest spider's thread, at times brought close together, combed in one direction without entangling, next stretched apart, and preserving in this evolution the most perfect parallelism among themselves, and at no time, and under no circumstances, confusing the fringes of the two threads; — they may cross each other, they may be apparently entangled throughout their length, but let the animal suddenly con-

tract, and all these innumerable interwoven fringes unfold, contract, and disappear, reduced, as it were, to one little drop of most elastic India-rubber. Week after week I have preserved these animals alive, and have never been tired of comparing again and again their changes in these thousandfold developments of their appendages. I have called together those who felt the slightest curiosity for such objects, to witness these phenomena, and have found them all interested to the utmost; and if I have any thing to regret, it is not the time lost in this contemplation, — for the more I became familiar with the sight, the more I was compelled to admire its beauty, and to contrast with the new forms presenting themselves before my eyes those different states with which I had been familiar before, — but it is the circumstance that the duration of their life is limited to a few months, and that I could not have a larger number of philosophic observers to contemplate with me these marvels, and that the time was too short to trace all the details of their structure microscopically; although I am aware that I have noticed many particulars which had been unnoticed before.

The chief difficulty in the comparative study of the different genera of this family arises from the circumstance, that they move permanently in different directions, some having the mouth naturally turned upwards, and others downwards; and that, from not having perceived this difference, the parts placed in opposite positions have been compared with each other in the different genera, which on that account require a complete revision of their characteristics.

The type under consideration, for which I retain the name of Pleurobrachia, as the most ancient applied to species of this particular conformation, is one of those which is deprived of peripheric lobes, that is to say, in which the gelatinous body is undivided, and the mouth constantly turned upwards or forwards when in motion; while the genus Bolina, to which I shall next call attention, is one of those in which one extremity of the sphere is split into two lobes, between which the mouth is situated, and in which this opening is almost constantly turned downwards when the animal is moving, though sometimes, when the animal is at rest, it turns in the opposite direction, opening widely its two lobes. It will be obvious how great mistakes may arise from comparing two animals constructed upon the same plan, but kept in a reversed position when contrasted. The difficulty of a thorough comparison of all the genera of this family is further increased by the circumstance, that genera without lobes or with slight indentations move naturally in the same position as Bolina; or in a position the inverse of that of Pleurobrachia. Such is the case, for instance, with Alcinoe, while Dellechiaja, with its very complicated lobes, moves in the position of Pleurobrachia.

Unhappily, all these animals have been figured without reference to the natural position in which they should be compared, and, no allusion to these prominent differences being made, it is hardly possible to reconcile the descriptions of one author with those of another.

The genus Pleurobrachia is limited to those species of Beroid Medusæ in which the body is nearly spherical or slightly elongated, the locomotive fringes extending from the margin of the mouth all round the sphere, in eight vertical rows, towards the opposite centre, where they approach very near to each other. This genus differs from Cydippe chiefly in the extensive development of the rows of locomotive fringes, which, in the latter, do not extend below two thirds of the whole height.

I know at present only two species of this genus sufficiently well characterized to be recognized as distinct species; one, the *Pleurobrachia* common on the northern shores of Europe, and the other that *Pileus* which I have observed on the eastern shores of the Northern United States, and for which I propose the name of *Pleurobrachia rhododactyla*, from its long, light rosy-colored tentacles.

Though almost spherical, this species is slightly compressed in the vertical plane of the two tentacles, so that one diameter, at right angles with the base of the tentacles, is somewhat shorter than that which would pass through their points of attachment.

As it is of great importance to the full understanding of the internal structure of this animal, and the correct appreciation of all its organs, to form a correct idea of their respective location, I feel compelled to enter into some tedious details respecting this slight variation from the spherical form; for though scarcely appreciable, it has a direct connection with the bearing of all the organs, which, upon close examination, are found to preserve throughout a constant relation to this apparently insignificant difference between the diameters; so much so, that these globular animals are truly bilateral in the arrangement of all their parts.

In the first place, the mouth is split transversely, and there is upon the opposite pole of the sphere an oblong, narrow, circumscribed area, placed also in the same direction, transversely to the longer diameter. So that the two tentacles with their bases are placed at right angles with the transverse split of the mouth and the opposite transverse area, the former being in the longer diameter, the mouth and the area in the shorter. The rows of movable fringes alternate, two and two, with these four radiating directions. So that there are four rows on one side of the plane passing through the tentacles, and four on the other; and also four on one side of the plane passing through the mouth and the opposite area, and four on the other,

no one being placed either in the prolongation of the mouth, or in that of the bases of the tentacles (Plates III. and IV. Fig. 3 and 4).

Again, owing to the slight flatness of the body, the four rows of fringes have their upper and lower arms bending in a somewhat different manner, so that there are two pairs perfectly parallel with each other along the prominent side, inclosing the base of the tentacles, which are perfectly equal, and two other pairs along the flattened side, inclosing the prolongation of the angles of the mouth and the transverse projections of the opposite area. The consequence of this arrangement is, that each segment of the body has two unequal rows of locomotive fringes placed in a corresponding symmetrical manner opposite each other, side by side, or crosswise.

Having thus ascertained that the body of this animal is not truly circular or spherical, and that there is a medial axis, with reference to which the arrangement of parts is regulated, their four planes meeting at right angles, one of which passes through the longitudinal diameter of the mouth and the corresponding diameter of the opposite area, and another through the bases of the tentacles, which are prolonged into the interior of the body, the question at once arises how we should consider these rays; whether the mouth should be placed upwards or downwards, or whether it should be considered as the anterior extremity. As with the other Medusæ, whatever view we take of the subject, when we compare these animals with either Polypi or Echinoderms to ascertain their homologies, we must, as a matter of necessity, bring them all into the same respective position, and contrast the arrangement of their parts in their mutual correspondence. There is, therefore, no difficulty about this point, inasmuch as the mouth is made in every case the central point of comparison. But it has been ascertained that Polypi, though absolutely radiated animals, have in most of their types, if not in all, a rudimentary indication of a longitudinal axis in the oblong form of their mouth, which is the first indication in the animal kingdom of a bilateral symmetry, occurring even among the lowest Radiata, while in Echinoderms it rises higher and higher, and becomes so prominent in Spatangoids as to influence, not only the general form, but even the number and arrangement of the internal parts, and the length and special development of the external appendages and the ambulacral rows.

The class of Acalephæ, which is intermediate between those of Polypi and Echinoderms, holds in these respects also an intermediate position. Here we have a slightly compressed body and an oblong mouth. But the mouth opens in a direction transverse to the elongation of the body. The question therefore is, Does the mouth, with the plane which passes through the mouth and the opposite area, indicate the

length of the axis of the body, and divide it into a right and left half, and are therefore the tentacles lateral appendages, one on the right side and the other on the left side, as we should consider them if we place the axis of the mouth in the same direction as the axis of the mouth in Polypi, or have we to consider the tentacles as arranged along the longitudinal axis, one on the anterior and the other on the posterior extremity? And in that case, is the split of the mouth rather the first indication of an upper and lower lip, — as we should consider them were we to compare the transverse position of the mouth with the position this opening assumes in the oblong symmetrical Echinoderms, in which the bilateral symmetry has been made prominent, — or have we to view also the indication of bilateral symmetry among Polypi as a tendency to such an arrangement between the two lips? I think I can be positive in the case of Polypi; for in Actinia, as well as in Astrangia, the oblong fold of the mouth is unequal in its two angles; and it were to suppose the right and left angle of the mouth to be unequal, and the upper and lower lip to be symmetrical, if we do not agree to consider this split as running in the longitudinal axis. And that it indicates really a longitudinal axis is shown by the circumstance, that fecal matters are discharged along the rounded angle of the oblong mouth, opposite to which there is in many Polypi a tentacle of a peculiar form. But this being the case, are there reasons to view Pleurobrachia in a different light? Are they really in their arrangement more nearly related to Echinoderms than to Polypi? I hardly believe it; for, as the mouth is transverse in so many Echini, their anterior and posterior extremities always differ more and more, in the same proportion that the bilateral symmetry is increased and made more prominent. It seems to me, therefore, more natural to compare Pleurobrachia with the other Radiata in a position in which the split of the mouth will indicate the antero-posterior diameter, even though the diameter considered as the transverse be thus greater than the longitudinal. This is, however, not the only instance of this case in the animal kingdom. In many Mollusca of the class Acephala, in the family of Cardiacea and Brachiopoda, we have numbers of genera and species in which the longitudinal axis is shorter than the transverse. And though the vertical rows of locomotive fringes may remind us of the ambulacra of Echinoderms, I still hold that such a position as I assign to them is in more direct accordance with the general progress of symmetry among Radiata than the reverse. The first tendency beyond the pure radiated arrangement which is introduced among them is to a symmetrical disposition and parity between right and left, even if the anterior and posterior extremities be marked only by this lateral symmetry, and are not made to differ from each other. Next, the two ends of the antero-posterior diameter are made to

differ, and this we see introduced only among the higher Echinoderms. For, though bilateral symmetry can be recognized among star-fishes and Echini proper, their anterior row does not yet differ, and the first appearance of such a difference is introduced in the family of Clypeastri, and more developed in Spatangi. If, therefore, the Echinoderms, which as a whole rank above Medusæ, still retain so much of the radiated type, and the bilateral symmetry is developed in them among so many of their types solely in the perfect symmetry of right and left, without a difference between forwards and backwards, why should we expect this still earlier in the class of Acalephæ, especially when we are able to refer this type so easily to that of Polypi? I assume, therefore, decidedly, that the diameter which corresponds to the split of the mouth indicates the longitudinal axis, and shall, in the following pages, describe all parts with reference to this view. I thus consider the halves of the body which would be divided by a plane passing through the split of the mouth, and through the opposite oblong area, as the right and left halves of this animal, and therefore the tentacles as being placed right and left. But I must for the present leave it doubtful which is right and which is left; for the sides are so completely identical, the two angles of the mouth are so absolutely equal, the prominent projections of the opposite area so uniform, as to afford no indication upon this point. This is a very remarkable circumstance to occur in a class intermediate between two others, in which the anterior and posterior margin can be fully ascertained in the radiated arrangement, even in the Polypi, though they rank lower. Is there, however, not a compensation for this difference in the greater symmetry of the two sides, as there are only four rays upon which the development of the animal takes place in Medusæ, while in other Radiata the numbers are odd? But, again, among Polypi, in the family of Halcyonoids we have the tentacles strictly in pairs, and here, also, the oblong opening of the mouth passes between the four pairs of tentacles, in such a manner as to render the anterior and posterior extremities absolutely equal. In this respect, Alcyonium would agree with Pleurobrachia, and justify the position I have ascribed to its bilateral symmetry. In another great type of the animal kingdom, we have a similar, though inverse case, in the family of Brachiopods, in which the anterior and posterior extremities are perfectly symmetrical, but in which the right and left are widely different, and a pair of tentacles which, in some respects, might be compared to the tentacles of Pleurobrachia, placed forwards and backwards. So that, if we were justified in taking our standard of comparison from the arrangement of parts in another type, there could be no hesitation in considering the greater diameter of Pleurobrachia as the antero-posterior diameter, and one of the tentacles as the anterior and the other as the posterior, and the mouth

as transverse. But here then right and left would remain doubtful. For the reason above alluded to, I have, therefore, no hesitation in tracing my comparisons through all the classes of Radiata, and introduce here the Brachiopods only that they may be remembered in this connection. The parts already mentioned in a general way are not the only ones which have reference to the bilateral arrangement. The tentacles arise in two sacs, extending inwards in a vertical direction towards the opposite side of the body, and reaching a point about as far below the higher centre of the animal as the point from which the tentacles issue is from the lower centre. These sacs are connected with another very large sac, giving out two wide hollow forks in opposite directions in the transverse diameter of the body, which branch at right angles parallel to the longitudinal diameter, and again give out each a branch at right angles, that is to say, parallel to the transverse diameter, thus forming the eight forks of eight hollow tubes, following for their whole length the inner surfaces of the eight vertical rows of locomotive fringes. The position of this complicated system, therefore, presents a regular symmetry, two main trunks penetrating symmetrically right and left from the central cavity, and branching in such a manner as to reach on each side with four arms the four vertical rows of locomotive fringes, and also to supply the sac from which the tentacles arise. This cavity is full of liquid, which is in constant movement by the agency of vibratory cilia, but also under the influence of a regular pulsation of the system in the two halves of the body, which alternate in their contraction and dilatation; so that at one time the fluid moves, to a considerable extent, from one side to the other, and next returns by the contraction of the opposite side through the same tube in the opposite direction, presenting something similar to what exists in Salpa, under circumstances differing considerably, however, as will be shown presently. The point to which I now wish especially to invite attention is the circumstance, that there is a large central cavity branching in a very symmetrical way in the right and left parts of the body, and undergoing a rhythmic movement of contraction and dilatation, alternating between the two sides. This cavity, which I shall call the chymiferous cavity, is not to be mistaken for the digestive cavity, which constitutes a sac within it hanging downwards from the mouth for about two thirds of the length of the animal, but which communicates with it in the same manner as the digestive cavity of Actinia communicates with the main cavity of the body. This chymiferous cavity finally has two apertures, by which it communicates with the surrounding water, and through which it discharges the refuse chyme. These apertures are placed in a symmetrical position on the two sides of the area opposite the mouth near its centre, obliquely opposite each other, so that one is in the anterior half upon one side of the body, the other in

the posterior half upon the other side. These openings are generally shut, but they open at intervals to discharge the fecal matters, and are afterwards instantaneously shut again. It is very difficult to catch these movements, and even after I had seen them open and shut, I have frequently watched days for them without observing a repetition of the operation, which I have, however, seen so many times now, that I entertain no doubt respecting the position of these openings, and their natural function. Moreover, balls of fecal matters will almost constantly be seen floating with a rotating motion below these apertures.

This sketch gives as yet but a slight, very incomplete, and superficial idea of the remarkable complication of structure which may be observed in these animals. But such a preliminary illustration was necessary before undertaking a minute description of all parts and their natural relations, and before alluding to these details I would request the reader to bear the following points in mind; — that Pleurobrachia is not strictly spherical, nor even strictly circular, in its somewhat elongated form; that there is a longitudinal axis, which passes through the mouth and the area opposite; that the tentacles are in the longer axis, at right angles with the fissure of the mouth; that the digestive cavity hangs in a large circulatory cavity branching symmetrically in the right and left halves of the body, the branches, eight in number, reaching the eight vertical rows of locomotive fringes, two other branches providing the sacs from which the tentacles issue, and two others following the walls of the digestive cavity, these four latter rising from the main lateral stems of the central cavity along the transverse diameter, the forks supplying the locomotive fringes, on the contrary, branching first parallel to the longitudinal diameter, and emitting each another fork parallel to the transverse diameter; so that all parts have a precise geometrical relation to each other; and finally, that the right half of this system alternates in its contractions with the left half.

In the special investigation of the minute structure of the different systems of organs developed in these animals, it will be better to proceed in such an order as will assist us in the understanding of all the other systems, rather than upon a physiological principle.

Though the form is apparently well determined and regular, even superficial investigation will satisfy the observer that it is constantly changing within more extensive limits than the appearances would lead him to suspect. In the first place, the apparently spherical form is not only frequently altered into an ovate by the elongation of the mass, but it even assumes, at times, a form rather cylindrical than ovate, especially on the side of the mouth, by the extensive dilatation of this opening. The changes which the mouth assumes in its outlines are very extensive and frequent. When shut, and

completely shut, it disappears almost entirely, and its position is scarcely marked by any thing more than an indistinct outline, towards which the upper ends of the rows of locomotive fringes converge. When half-way open, or while opening, it assumes an oval form, like a fissure across the body, which becomes gradually more and more elongated, then widens, and finally expands into an ample circular funnel-shaped depression. (Plate II. Fig. 1, 2, 5, 10, and 11; Plate III. Fig. 3; Plate IV. Fig. 3 and 5; Plate V. Fig. 3, 4, 5, and 6.) These movements are rather slow, and may be compared to the undulations of a slug or snail adapting its mouth to the form of its food. The changes in Pleurobrachia, however, do not seem to be called forth by the approach of food, but are rather the result of a natural disposition in this animal to be in an attitude ready to seize upon its prey. The movements are regulated by powerful bundles of muscular fibres arranged in a very regular manner. At first it would seem as if the whole mass of the body were equally gelatinous and transparent. But upon close examination, and even under a slight magnifying power, the large development of muscular fibres throughout these bodies is readily seen, and explains fully the easy movements of these animals, and the readiness with which they change their form.

The arrangement of these muscular fibres being most easily understood in their connection with the vertical rows of locomotive fringes, and the form and position of the circumscribed area opposite the mouth, I shall begin this illustration by some details upon that apparatus. The vertical rows of locomotive fringes (Plates I. to IV.) are entirely superficial. The fringes themselves (Plate II. Fig. 6) seem to be modified epithelial cells, for whenever, in the progress of decomposition, the epithelium is dissolved in the space between the fringes, it is easy to trace the decomposition of the tissue into this apparatus, even where the muscular fibres immediately below remain unaffected. Each vertical row consists of a great number of isolated, transverse, comb-like fringes, placed one above the other, and movable, either isolately, or in regular succession, or simultaneously. Each comb consists of a large number of thread-like bristles, slightly arched upwards and downwards, of which the middle ones are the longest, tapering gradually sideways, so that the combs are, properly speaking, crescent-shaped, with a straight base, the teeth or fringes of which are movable in quick vibrations, up and down, independently in each comb, and even independently to some degree in each portion of the same comb, as the middle fringes may be seen to move when the lateral are motionless, and *vice versâ*. But generally all the fringes of one comb act simultaneously; but the motion in all the many combs of one row is successive, so that, when the combs are very active, they seem like waves moving up and down in rapid succession along each vertical row, or like the waving spikes in a cornfield agitated by

the wind. Again, the undulations of the different rows are independent; sometimes all the rows playing at the same time, at other times parts of the rows, or parts of each row, or parts of some rows, playing independently.

I have been unable to ascertain what is the structure of the fringes themselves. They seem to be stiff, and nevertheless they are too soft to be gathered for chemical analysis. They must be decidedly of a peculiar tissue, for their appearance is quite peculiar, and does not resemble that of the other tissues. The number of teeth or fringes in one of the larger combs may be about fifty, but they are not equally numerous through all the combs in one vertical row. The combs in the upper parts and in the lower parts of each row, nearer the mouth and the area opposite, are gradually shorter and shorter, and contain fewer and shorter fringes, the largest being about the middle of the vertical height. They terminate rather abruptly above, and at a greater distance from the centre than below, where they are naturally prolonged towards the central eye-speck; if the black tubercle in the centre of the circumscribed area opposite the mouth is really to be considered as an eye-speck.

The movements of these fringes seem at first to be identical with those of vibrating cilia; and one might be tempted to suppose that these locomotive fringes are formed by a row of compressed vibrating cells, arranged in such a manner as to bring their cilia in one row, and the cells themselves in such superposition above each other as to form vertical series. But the cilia or fringes are far larger than any vibrating cilia ever described, and their motion shows distinctly that they are under the voluntary control of the animal; for their movements are neither incessant nor constantly equal. They are at times accelerated or retarded, entirely stopped and resumed at shorter or longer intervals; so that the evidence of their voluntary movement is as full as can be, and, indeed, the structure which determines the movements is the same as in all cases of voluntary motion. A regular muscular apparatus can be traced along the base of each comb, muscular fibres forming a regular row above and below the base of the fringes, by the repeated contractions of which the fringes are moved up and down like flappers, in quick succession. But notwithstanding this muscular apparatus, which may be compared to a pennate muscle, the axis of which would constitute the point of insertion of the fringes, and thus control their movements up and down, it is hardly possible to refrain from the idea that these fringes are, after all, in some way or other, connected with vibratory cilia, — that they are vibratory cilia on a gigantic scale. And I do not see why there should be nowhere in the animal kingdom a transition between a particular arrangement of muscles moving independent appendages, and the structure of a ciliated cell regulating the motions of its own vibrating fringes. And if this

view is natural, it will probably be found that the vibrating locomotive fringes of Pleurobrachia are, among the many complications of animal structure, precisely that step in their development where the complication of the isolated cilia has reached its extreme, and has been made the foundation of a higher stage of development, in which the parts, which, in the primitive cell, were simply structural complications, assume an independent existence, developed by the growth of new cells.

Fully to understand the character of the vertical rows of locomotive fringes, it should be borne in mind that they are connected for their whole length with vascular tubes following the same course (Plate III. Fig. 1 to 4), and which arise from the great central chymiferous cavity. This intimate connection leads naturally to the supposition that, besides their functions as locomotive organs, the vertical rows of fringes are in some way connected with respiratory functions, and that there is between these two systems the same natural physiological connection which exists in Echinoderms between the inner branchiæ and the ambulacral tubes; or in Worms, between the respiratory vesicles and the locomotive bristles.

The circulation of fluids, and the respiratory movements connected with this circulation, are almost throughout the animal kingdom in direct communication with locomotion, even in the higher animals. Among Polypi the dilatations and contractions of the body renew constantly the water which fills their cavity, and provide them with a fresh supply of aerated water. The same is the case among Medusæ. For even where there is no distinct individualized system of respiratory organs, it is obvious that a constant renewal of the surrounding medium, by means of which oxygenation takes place, is an essential condition for the maintenance of life; and where there are no special organs adapted to this purpose, the main movements of the body supply the deficiency. The water-pores in Echinoderms, through which their main cavity is constantly filled with fresh sea-water, undoubtedly perform a similar office. Again, among Mollusca, respiration and locomotion are still more intimately connected; but in a manner which differs decidedly from what we observe in higher animals. For there, by the dilatation and contraction of the respiratory cavities and the circulation of the blood through the respiratory organs, the body is amply supplied. But unless Acephala open their valves, unless they expand and contract alternately the whole body, the supply of fresh aerated water must be much less; and I doubt whether oysters and clams could be kept alive if their valves were shut constantly by pressure, and muscular motion, contraction and expansion of the large bundles which preside chiefly over locomotion, were prevented from coming into play in aid of the vibratory cilia of the mantle and gills. The manner in which the respiratory cavity is shut in so many Gasteropods,

unless the fleshy parts are fully expanded, shows plainly that here again there is an intimate connection between respiratory movements and locomotion. In Cephalopoda this is still plainer, for, from the form of the respiratory cavities, from the disposition of the sacs in which the gills are placed, we can easily infer that the contractions and dilatations of these sacs, by which the water is renewed, must afford a material mechanical assistance in the progress of locomotion. Again, throughout the type of Articulata, this connection is most intimate, the respiratory organs being directly connected with the locomotive appendages, forming, indeed, parts of the various kinds of oars, fins, legs, and chewing appendages, by which the principal motions of the body are sustained. Not a joint can be moved here without influencing respiration, and, again, the expansion and contraction of the respiratory cavities, the filling of the respiratory vesicles, or the large circulatory sacs connected with the gills or fins, and the introduction of air into the tracheal tubes, must, in their turn, influence locomotion. And it were a subject well worthy of the attention of physiologists, to trace more minutely this double connection throughout the animal kingdom. Perhaps the type of Articulata is best adapted to make a beginning in these investigations. For among them, in the Crustacea, for instance, the chewing of the food itself is directly connected with the process of respiration. The motion of the jaws aids in forming and maintaining a regular current of water along the gills through the respiratory cavities, and even when otherwise not employed, the jaws are kept in motion in some degree to assist respiration. And it can hardly be doubted that the process of respiration also materially aids the insects in their flight, and that the state of expansion or contraction of the respiratory cavities is very different in the state of repose, or during flight. While watching locusts, I have often been struck with the state of wide expansion of their abdomen at the moment they start, and with the collapsed state of the whole body soon after they have alighted, which is even so great as to prevent their rising again immediately when chased.

Again, among Vertebrata, we find in fishes that the respiratory movements — the lifting and shutting of the operculum, the filling and emptying of the branchial cavity — aid the fish in slowly progressing; so much so, that when resting upon the bottom of a glass jar, apparently immovable, these animals are at times suddenly propelled forward under the action of a powerful occasional contraction of the branchial cavity, even if the ordinary locomotive organs, the tail and fins, remain absolutely quiet. How close a connection exists between locomotion and respiration in the Ichthyoid Batrachians, I have often had occasion to witness in a Proteus kept in confinement, in which the gills grew gradually paler and paler if the animal was absolutely motionless, but would instantly be

filled with a large quantity of blood, and appear intensely red, after some violent motion. It might be objected, that this is a mere influence of locomotion upon circulation; but if there were not this natural disposition in all locomotion to influence the process of respiration more than any other system, why should not the blood, when such powerful motions take place, be accumulated in any other part of the body, — for instance, in the tail, which is the very cause of the motion, — rather than in the gills? In birds the extensive development of the lungs, the prolongation of air-sacs into the abdominal cavity, the wings, and the sternum, in those most remarkable for their power of flight, plainly indicate again the most strict connection between locomotion and respiration, though the nature of this connection be perhaps different from that which is observed in the lower classes. Nevertheless, it exists and can be traced to a very remarkable extent. We cannot fail to trace, also, similar relations among Mammalia, though here the influence between the two functions is not so direct. However, it must be acknowledged that it is extensive enough, when we consider how the aquatic types have to accommodate all their movements to the wants of the system for atmospheric air, and remain constantly within reach of the surface, in order to be able to return to it in a short time. How much the breathing is affected by violent movements is so well known to every one, that the existence of accessory muscles of respiration in Mammalia, the antagonism between the pectoral and abdominal muscles and the diaphragm, the use of belts by athletes in running, leaping, or wrestling, need hardly to be further mentioned as evidence of this mutual relation. Of course, in animals in which all the functions have reached a great degree of independence, they are no longer subservient to each other to such a degree as they were in the lower types; but even the unpleasant influence which excessive exercise of the locomotive power has upon respiration in the higher animals shows the intimate relation which prevails in the plan of organization.

One peculiarity which might be mentioned as indicating a further connection between locomotion and respiration, if the vertical rows of locomotive fringes are at all connected with respiration, is the circumstance that they serve, for their whole extent, as points of attachment for the muscular system, as we shall see presently when describing the contractile tissue. This connection, also, may remind us of the connection which exists in Vertebrata between the anterior limbs and the chest.

When examining the structure of the vertical rows of locomotive fringes, we encounter considerable difficulties, to which I would call special attention, for the benefit of those who may have an opportunity to repeat these investigations. The best way to study their peculiar structure is to cut off from the body a portion of the row, say three or four transverse combs, and to bring them separately under the

microscope. But then the fringes lie flat, and the tips of each upper comb cover the bases of the lower, so that their insertion connot be well understood unless an upper comb be entirely removed, as in Plate II. Fig. 6. The connection of the chymiferous tubes with these vertical rows of locomotive fringes may be no obstacle in the way of their study in their living, active condition, for then they are so distended and so full of fluid as rather to facilitate their study, as they appear like a transparent basis through which the external appendages are examined with great advantage. But when pieces are separated from the body, the tubes collapse, and contract so much as to form a narrow erect hose about the middle of the vertical rows, which I had for a long time taken for a particular organ, until I ascertained, by repeated investigations, that it was the chymiferous tube empty and contracted. In Plate II. Fig. 6, the outlines of this chymiferous tube are drawn in two different stages of contraction, *a* and *a* representing its outline when half empty ; *b*, *b*, when fully contracted. Again, vertical muscular fibres, and others crossing them at various angles, near the margin of the locomotive rows, may interfere with the study of their fringes, before one is fully acquainted with the subject. All these circumstances should be particularly kept in mind, when examining the muscular fibres of the base of the fringes, which act in moving them up and down, and which belong in their transverse rows to the isolated combs proper. These are best seen from the anterior surface of the rows, when a thin slice is cut in a vertical direction, and the combs themselves are placed upon the objective table with their base turned upwards. Finally, there are about this region other organs, the nature of which it has not been in my power to recognize, though they are constantly seen between the locomotive combs, alternating regularly with them, and placed about the third of their width. I allude to minute tubercles or ganglion-like swellings (Plate II. Fig. 6, 7, and 9, *o*, *o*), so small as to be, perhaps, simply isolated cells of a special character, but which, in the midst of the tissues, I have never been able fully to isolate. There are constantly two of them, or a pair, placed symmetrically, at equal distances between the single combs. Other swellings not so constant in their appearance occur in the middle line (*c*, *c*). These swellings seem to be united by a vertical thread ; but this thread, as represented in Fig. 9, may be a rudiment or a fold of the contracted chymiferous tube, as I never could find it equal in appearance in two specimens. The swellings in this line may be particles of the harder contents of the chymiferous tubes, accumulating in the intervals of the combs, and forming little balls, when the tube is finally completely contracted. But whatever may be the real nature of these bodies, those which occur regularly in pairs are certainly of a different nature ; for I have frequently seen distinct threads, or fibres, connected with them ; sometimes, as in Fig. 6,

arising at right angles with the vertical row, and extending sideways; at times diverging in four directions, as in Fig. 7; and at times the two kinds of fibres, though less regular, would appear in connection with them, as in Fig. 9. Whether these swellings, and the threads arising from them, are sensitive ganglia, sending out nervous threads, or whether their appearance, which is subject to so many irregularities, is the result of the contraction, and perhaps of the commencing decomposition, of numerous muscular fibres, lining the inner surface of the vertical rows of locomotive fringes, must remain doubtful. I should say, however, that I have never been able to discover these parts in the living animal, though they are readily found upon slices cut from it, often immediately after their removal. The appearance I noticed in the surface of the body between the combs, when kept apart, was always similar to what is represented in Fig. 8, where muscular fibres crossing each other in various directions were chiefly visible; and, below, were granules floating through the chymiferous tube, accumulating generally to a great amount in the centre (*a*), — owing, no doubt, to the greater diameter of the tube when seen in such a position, — and apparently fewer towards its margin (*b*), where the outline appears as a double line. But the great transparency of all these parts makes it exceedingly difficult to arrive at any precise conclusion, even with regard to their respective position.

With the spherical form characteristic of the family of Beroe, the general arrangement of the muscular bundles is also somewhat modified, though regulated by the same principle which prevails in the arrangement of the muscles in the Discoid Medusæ. Here, also, we have vertical bundles and circular ones, but, owing to the spherical form of the body, these extend all round the sphere from one pole to the other, like the meridians and parallels of an artificial globe, modified in the details of their arrangement by the form and extent of the mouth, by the disposition of the area opposite to it, and by the width and extent of the vertical rows of locomotive fringes, and also by the presence and position of a special cavity for the tentacles.

In Pleurobrachia proper, the vertical rows of muscular fibres are eight in number, alternating with the rows of locomotive fringes, beginning about the same height as those on the mouth side of the body, as is seen in Fig. 1, 2, 3, and 5, and extending to about the same distance from the opposite centre, where their arrangement, however, is considerably modified by the peculiar form of the circumscribed area of the anal end of the body. Six of these vertical bundles are nearly identical in their arrangement, but the two lateral bundles (Fig. 2), which extend in the direction of the axis of the tentacles, are somewhat modified by the opening from which the tentacles are issued, their fibres diverging and converging again, so as to have a direct influence upon the cavity in which the tentacles are contained.

Besides these main bundles of vertical fibres, we have as many more bundles alternating with them, which arise from the upper end of the vertical rows of locomotive fringes, and converge towards the margin of the mouth, combining their fibres more or less with those of the alternating bundles, and forming in their combination the powerful contractile apparatus which opens the mouth, and which, when this is shut, appears like a regular area of fibres radiating in all directions, as seen in Fig. 5 and 11, in which the mouth is absolutely shut, and contrasting most remarkably with that opening when spread to the utmost, as in Fig. 10. Similar fibres, though less regularly star-shaped, converge also from the lower extremity of the vertical rows of locomotive fringes towards the anal area (Fig. 4), but, from the peculiar form of the latter, and the curve of the chymiferous tubes around it, they have a somewhat peculiar arrangement.

The circular or parallel fibres or bundles of muscles (Fig. 1, 2, and 4) extend transversely from one row of the locomotive fringes to the other; and although transverse fibres pass under these rows, the circular muscular bundles cannot strictly be said to extend in unbroken continuity all round the sphere, in parallel, horizontal circles; for the chief bundles extend only from one row of vertical fringes to the next, their fibres being chiefly connected with the substance which gives attachment to the locomotive combs, and the number of fibres stretching across beneath being considerably reduced by the great development of the chymiferous tubes which follow the locomotive rows. Again, there are along these tubes, and under the locomotive combs, vertical fibres also, which interrupt the regular course of the circular ones, though the vertical fibres are here less powerful and less numerous than in the middle of the space between two locomotive rows, where the chief vertical bundles are accumulated. Towards the upper or mouth end of the body, however, above the vertical rows of locomotive fringes, the circular fibres seem to be circular all round the mouth (Fig. 10); or at least to form bundles which are crossed by the upper radiating muscular fibres, and interwoven with them, but not broken up into distinct segments of circular bundles. On the anal extremity of the body, the circular fibres are considerably reduced, though there are still some to be seen.

Considered isolately, the muscular bundles cannot be compared to muscles, as they exist in higher animals. They are, strictly speaking, isolated muscular fibres, loosely scattered, but more or less crowded together throughout the gelatinous mass, or upon some particular points of the body, and in particular directions presenting, when contracted, so much of a cellular appearance, as to be easily compared with elongated fusiform cells, assuming, indeed, frequently that appearance, and then passing again into a thread-like form, sometimes regularly swollen in the centre, at other times more to-

wards one or the other extremity, and assuming, therefore, alternately a clavate, or fusiform, or filiform appearance, very much elongated, but nevertheless sufficiently characteristic to be compared to cells, their nucleus being often still distinguishable, but presenting no appearance whatever of striæ across the fibre. From their appearance, and from the change of their form during contraction, I can hardly doubt that they are hollow, and contain fluid. The chief difference in the arrangement of these fibres in Beroid and Discoid Medusæ consists in the circumstance, that in the former the muscular fibres seem to pervade the whole substance of the gelatinous matter which constitutes the main mass of the body; and, indeed, it seems to me that this gelatinous mass is, in its elementary structure, identical with the contractile tissue which pervades it, with only this difference, that the cells which contain the jelly are less contractile, and their liquid contents more consistent. But that even these parts are not altogether deprived of the power of contraction and dilatation would seem to be conclusively shown by the circumstance of the whole sphere in the same individual appearing at times larger than at others. And if this is so, we have here a body made up, to a very great extent, of the same elements as the foot of a mollusk, for instance, but differing in so far as that there the cells are metamorphosed into more perfect muscular fibres, while here the elements of the cells preserve more of the primitive character of such structures, though they undergo also a peculiar modification, inasmuch as we have here an elastic jelly interspread with contractile fibres.

I have been unable to distinguish in Pleurobrachia a special superficial system of vertical fibres distinct from those within; nor are the circular fibres so exclusively internal as in Discoid Medusæ, but interwoven with vertical fibres throughout the thickness of the walls of the body, though the vertical fibres are generally more numerous in the outer part of the main mass, and the circular fibres towards the inner part; as may be seen when examining the mouth in its contracted condition, when the radiating fibres alone are visible externally, as in Fig. 5 and 11, while the circular fibres are chiefly shown when the mouth is fully extended, as in Fig. 10. Though the contractile fibres maintain throughout the body chiefly these two directions, it were an exaggeration to imagine that the fibres all run strictly in either one or the other of these directions. On the contrary, in each bundle or row of either vertical or circular fibres, we find that their course diverges more or less from the prevailing direction, and that, for instance, towards the upper and lower summit of the body, about the height at which the vertical rows of locomotive fringes terminate on the two sides, the chief vertical bundles of muscular fibres diverge to form somewhat pennate bundles of fibres, as in Fig. 4 and 5, and that along the sides of the vertical rows of locomotive fringes the

fibres also show a more or less pennate arrangement (Fig. 1 and 2). But the most particular disposition is in the two lateral bundles (Fig. 2 and 4), which above, towards the mouth, are at first similar to the other vertical bundles, but about the middle of their course diverge to inclose the bases of the tentacles, and form a sort of sphincter to enlarge and shut, in their relaxation and contraction, the opening of the cavity in which the tentacles are contained (Fig. 2, 3, and 4), *b* being a profile view of those bundles of fibres, *e* representing their termination upwards, and *d* their arrangement, when the aperture through which the tentacles issue is fully shut. The peculiar muscles which move the partition of the cavity of the tentacles will best be described with that system.

It has already been mentioned, that there is a wide cavity in the centre of the body of this animal, into which hangs the digestive cavity proper; but the natural relations of these parts are so difficult to appreciate, the ramifications of the cavities so complicated, and nevertheless so regular, and, again, so movable in their constant contractions and dilatations, that, with all the assistance of numerous drawings, as given in Plates III. and IV., I hardly expect to be able to give a correct idea of this apparatus, unless the reader is willing to consider attentively every point of the following description by itself, and to keep, at the same time, constantly in mind the relative connection of all parts, and their bearing upon the general disposition of the body.

In the first place, let it be remembered, and well understood, that the main cavity undergoes constant changes, as to its size and outlines, according to its temporary state of contraction and dilatation, and that both halves of the system of tubes, which arise from the main cavity and branch into the right and left halves of the body, alternate constantly in their contractions; so much so, that the one may be in the state of fullest expansion (Plate III. Fig. 2, *a*) when the other is in the most complete state of contraction; and, after a while, the reverse will take place, when *b* will be fully expanded, and *a* fully contracted. But in these alternate movements, there is a moment when both halves are in a state of apparent equilibrium, though one be in the process of emptying, and the other in the process of filling; but at the moment an equal amount of liquid has been pressed from that half which is contracting into that half which is filling, the symmetry is most complete. These alternate contractions are nearly as regular as the movements of diastole and systole of the heart, and take place by a constant balancing of the fluid alternately one way and the other. The difficulty of watching this singular circulation arises chiefly from the necessity of keeping the living animal in one and the same position in order fully to appreciate these movements, as the slightest obliquity will interfere with the perspective in such a manner as to make it altogether

impossible to follow the natural movements. Again, unless the parts are placed in such a strictly identical position, those which are in pairs will create confusion, as they may come into various positions presenting apparently a close connection with parts to which they are not all related. Again, the peripheric tubes extending vertically over the whole surface cover so easily the origin of the different trunks arising from the main cavity, that it is indeed very perplexing to trace them all in their true connection. Add to these difficulties the circumstance, that the arrangement of parts, owing to the bilateral symmetry of the body, appears entirely different when viewed from the side, in profile, and in front, and it will be plain that, unless one keeps in mind two distinct images of the various connections of all these stems and their ramifications, in a front view and in a lateral view, combining them in thought with the rapidity with which such an animal may revolve upon itself, it will be impossible for him to trace for a moment its structure while alive, and he will only have constantly before his eyes the tantalizing image of a piece of machinery apparently very complicated, the structure of which he has to decipher while it is moving, but moving almost too fast to allow him to seize the connection of the different parts as they pass along, and which is not only deranged, but destroyed, the moment it is stopped. It was under such circumstances that I undertook to study the circulation of these animals, and though I succeeded in injecting indigo into their main cavity, and in having it circulate for hours at a time within the body of the same animal before it died, and though I was satisfied that not a particle of the colored liquid had passed into any part of the body into which the liquid before it was colored had not naturally free access, and though it was thus plain to me, that, even after being colored, the circulating fluid continued its normal course, I must say that I never investigated a more difficult subject, never had to devote so much time to the same point, and never taxed my patience to such an extent, as during these investigations. I insist upon these details, and state them at full length, because I know that I have now cleared up this subject, and may perhaps induce some other student to go through the long description I am about to give of it, since he can expect to have the matter settled for him. Let us proceed in this description as we should with a minute description of the ramifications of the blood-vessels of some highly organized animal. The difference which exists between the digestive cavity and the main cavity of the body will first engage our attention.

In a front view (Plate III. Fig. 2), when the two tentacles appear right and left, and the plane which passes through the longitudinal fissure of the mouth divides the body into halves, we have before us, on our right, one of those halves of the body, which alternates in its contractions with the other half on the left. It is according to this

diameter that the antagonism between the two sides is introduced. Seen in this view, the digestive cavity appears throughout like a narrow fissure, *c* ; but as it is wider in another direction, its outline, as seen in Fig. 1, is very broad. The fact is, that this cavity is a flattened sac, flat as long as it is not full of food, and the two surfaces of the flattened bag are pressed upon each other; so that when seen in profile, that is to say, facing the longitudinal diameter of the body, as in Fig. 2, it appears like a mere double skin, or a slit lined with a membrane; but when seen from its broadside, that is to say, facing the right or left side of the body, as in Fig. 1, it appears like a wide sac, and only during the process of digestion is it swollen into a more rounded sac or cylinder. The lower extremity of this sac is projected into the main cavity of the body, terminating there in a large opening, which, at the will of the animal, can be shut or opened ; so that, like the stomach of Actinia, the central digestive cavity of Pleurobrachia communicates with the cavity below, or is shut up by itself. The difference between the two genera, however, consists in the limitation of the cavity of the body, which, as such, is circumscribed within the centre of the animal in Pleurobrachia, and sends off large trunks and tubes, branching diversely into its mass and along its surface, while in Actinia the whole body is hollow, and the stomach empties into that one large cavity.

The central cavity has two main stems, one extending into the right, and the other into the left half of the animal, as is seen in Plate III. Fig. 2, 3, and 4. It would seem from Fig. 2 as if the largest sac were hanging loosely in the central cavity; this is not the case, however, for the spaces communicating with the main cavity right and left of the digestive sac in this figure do not form a continuous cavity encircling the whole digestive sac, but are only two tubes, which arise from the main trunks of the central cavity, and follow the middle of the lateral surface of the compressed digestive sac, in an ascending course, up to the margin of the mouth, being simple narrow tubes, as Fig. 1 shows. Downwards, however, the main cavity extends in the form of a funnel, terminating with two holes near the centre of the area below. This funnel descends in the centre of the animal vertically, and lies, therefore, in its central axis. It assumes nearly the same appearance in whatever position it is seen, excepting, however, its termination below, which is furcate when seen from the side, as in Fig. 1, and simple when seen in front, as in Fig. 2. This part of the cavity and the main lateral trunks being, as it were, the centre of the circulation, we may view it as an axis which branches right and left, and which rises in the centre in two parallel forks up to the mouth ; so that, when seen from the side, the double upper fork is seen as one, but the lower fork, which is at right angles with the former, is distinctly seen, and *vice versâ ;* the main lateral stems and their ramifications present in the first position their broadside, and appear foreshortened in the other.

The two main lateral trunks (Fig. 2, *a*, *b*) branch off at right angles from the central cavity, and extend horizontally for some distance sideways, ascending slightly, changing their position, however, to some extent, according to the state of contraction or distention of the digestive cavity. Five branches arise on each side from these main trunks, or rather three, as we may view them. Perhaps some observers would say four, and really it is difficult not to exaggerate their connection, or to distinguish sufficiently between their branches. The fact is, that, before branching again, the two main trunks form, at their extremity, sideways, a sort of dilatation, from which arise two lateral branches extending horizontally backwards and forwards, and two close together, which may therefore be taken for one, ascend in a vertical direction upwards. Thus the main branches from the first trunks are either three or four, as we consider the vertical one as two parallel stems or only as one; but as the branches extending horizontally forwards and backwards give out not far from their origin two others, which extend also horizontally sideways, nearly at right angles with the former, and as all these branches originate so near the point where they communicate with the primitive main trunks, they may all with almost equal propriety be considered as arising directly from it. And if this view be taken, the main trunk may be said to have five branches, four horizontal ones, and one with two parallel tubes ascending vertically. The fact is, that the termination of the main trunk may contract or dilate in such a manner as to present alternately these different aspects. For instance, in its most contracted state, when seen from above, as in Fig. 3, there are distinctly six branches arising from the main horizontal trunk, the two vertical ones appearing like very short tubes, though they are actually as long as the others, because their whole length is foreshortened upon their origin, while the four horizontal branches are seen for their whole extent, two and two, however, united by their base; so that it may with equal propriety be said, that on the whole there are only four tubes, the two horizontal ones branching soon again into two; or, in the dilated state of the main trunk, when the branches arising from it are in a state of contraction, they all seem to originate from one common cavity, as represented in Fig. 4. Here the four horizontal tubes really seem to arise independently of each other, and the two vertical ones are brought so close together as to appear like one, making altogether five branches. In another state of contraction, the two vertical ones may seem united, and the two pairs of horizontal ones also, when there appear to be only three branches to the main trunk; and, unless the dilatations and contractions of these curious ramifications of the stems have been watched for a long time, these differences may remain unnoticed, but when fully understood, there is no contradiction in the apparently conflicting statements that there seem at times to be three, at times four, at

times five, and at times even six branches to the main trunk. I should add, that, when seen from above or from below, unless the body is somewhat inclined, the vertical tubes altogether escape attention, and that the best position to ascertain their relative connection is a somewhat oblique external side view, as in Fig. 5. In Fig. 1, which represents the whole system in the same position, the view of the horizontal main trunk and its branches is somewhat confused, from the circumstance that it is projected upon the vertical central cavity, and the prolongation of that cavity upwards and downwards; but in Fig. 5 we have only the peripheric branches arising from the main trunk, that is to say, the portion seen to the right of Fig. 2, 3, and 4; while in Fig. 1 we have, besides that half, the central axis also, as likewise in Fig. 2.

I have described these peripheric branches as horizontal, and so they appear when seen from above or from below; but in a vertical position they are seen to be somewhat deviating from the same horizontal plane, the main branch reaching the periphery somewhat higher than the secondary branch, and the vertical branches inclining slightly outwards. These different branches have by no means the same functions, and are not connected with the same apparatus, the vertical branches extending into the peduncle or cavity from which the tentacles are protruded, while the horizontal branches communicate with vertical tubes, which follow the inner surface of the vertical rows of locomotive fringes for their whole extent.

As there are on each side four such horizontal branches and four vertical rows of fringed combs, there are also, in the whole, eight vertical superficial, chymiferous tubes, widest in the middle, and tapering upwards and downwards, which are in most strict communication with the central cavity through the four horizontal tubes, and the two main trunks, from which they themselves arise. The upper ends of the superficial vertical tubes, which I may call the ambulacral tubes, terminate apparently in a blind point; at least, I have been unable to trace a direct communication between any of them and the vertical tubes which follow the sides of the digestive cavity, though such a communication is seen in the genus Bolina, as I shall mention hereafter; it may, therefore, have escaped my attention in this genus. But whether there be such communication or not, the fluid circulated upwards through these tubes can be distinctly seen to retrace its way downwards; so that, in the ascending branch of the ambulacral tubes, the fluid injected through its horizontal branch is moved up and down alternately. This is also the case with the lower branch of the same vertical tubes, though the lower end tapers gradually into very slender tubes, which extend as far as the anal area, and unite there again with the central cavity. But this termination of the central tubes being too narrow to allow all the liquid injected into the larger stem to pass through, the

liquid moves here also up and down. The movement, in reality, takes place in the following manner. Each of the eight horizontal tubes fills its vertical ambulacral branches, the fluid flowing, at the junction of the horizontal tube with the vertical stem, in two opposite directions, upwards and downwards. A small quantity passes through the narrow prolongation of the tubes below back into the main cavity; but the greater portion flows back during the contraction of the mass which has been moved upwards, is pressed into the horizontal tube, and returns to the centre of the movement to pass into the opposite side of the body. It may be, also, as mentioned above, that a small portion of the fluid passes through exceedingly minute tubes into the vertical tube of the stomach, and back into the central cavity, in the same manner as upon the anal extremity, as this is really the case in Bolina. However, this communication above and below is too narrow to establish a direct onward circulation; the liquid moves decidedly to and fro in the ambulacral tubes, and returns chiefly to the central cavity through the horizontal tube, and, what is still more interesting, the dilatation of the four tubes of one side alternates with the dilatation of the four tubes of the opposite side. Moreover, in each vertical ambulacral tube, the motion of the fluid is an undulatory one, owing to the alternate dilatation and contraction of the tube itself, as shown in Plate II. Fig. 6. The movement of the fluid in these tubes can be traced very satisfactorily, when following the course of the minute granules of colored matter suspended in the water after injection; but even in fresh specimens uninjected, the circulation can be tolerably well traced by watching the small particles of undigested food suspended in the mixture of water and chyme which is circulated throughout this system. As in Polypi, the whole mass of digested food, comminuted and reduced to a very uniform state, but in which the parts capable of being assimilated are still mixed with the refuse matter, is indiscriminately emptied into the main cavity of the body, and, with a certain quanity of water introduced in the same way into this cavity through the mouth, kept in a constant regular undulatory circulation throughout life. But as there is a double outlet through which this system can discharge its contents on the side of the anal area, the circulation is more or less active, all the tubes more or less turgescent, and the whole cavity more or less dilated, as the quantity of fluid in circulation is greater or less, which, to some degree, changes the relative position of the tubes and the central cavity. When very full, the wider central space is considerably raised, while in a state of relaxation it sinks lower down, nearer the anal extremity of the body. As long as the circulatory system is relaxed, the ambulacral tubes are very much contracted, their diameter is much less than under other circumstances, and by no means equals the width of the vertical rows of locomotive fringes; but when turgescent and full, they swell beyond their width. The

force which acts in propelling the liquid through the system is not the same throughout. The alternate contractions of the two sides result from the muscular contractions of the two sides of the body regularly alternating; but the main cavity in its central parts is entirely lined with vibratory cilia, so that even when the body is perfectly at rest the fluid is maintained in a constant rotatory motion through their agency. I have repeatedly and distinctly seen these cilia playing round the lower opening of the digestive cavity, and upon the walls of the vertical, central, circulatory cavity, as well as upon the walls of the main horizontal stems, and upon the walls of the inferior vertical funnel, even as far as its two forks which diverge below. I have been unable, however, to discover similar cilia within the secondary horizontal tubes, or the vertical ambulacral tubes. I have also failed to discover them in the vertical tubes of the tentacular cavity, though they may exist there also. However, the contractions of this latter cavity by muscular power are so extensive, that the agency of vibratory cilia does not seem to be required to keep the fluid in motion in that part of the system. I should nevertheless add, that even the walls of the central cavity, where they are most distinctly lined with vibratory cilia, are also fibrous, and that these fibres are distinctly contractile, and the capacity of the cavity is not only increased and reduced in a passive manner by the accumulation of fluid or its expulsion, but also actively by the contraction and dilatation of the walls themselves. How the contents of this circular system are diffused into the substance of the body for nourishment is not very plain, as there are no capillaries, but everywhere broad tubes. From the structure of the whole mass, however, we may infer that assimilation takes place by a process of endosmosis and exosmosis. If this view is correct, we should consider the two ascending tubes upon the middle walls of the digestive cavity as the nourishing vessels of the stomach; the two main horizontal trunks as two respiratory vessels, branching into eight branchial vessels, which are the main trunks of the eight ambulacral vessels; and the vertical funnel below as a vascular cloaca, discharging its contents through two distinct apertures on the sides of the anal area near the lower centre.

The vertical tubes ascending into the sacs from which the tentacles issue seem to have a peculiar function, and to be directly connected with the movements of the tentacles, and these movements, again, to be connected with the alternate contraction of the two halves of the body, as there are no parts which undergo so extensive changes in their size, and in their state of contraction and dilatation, as these sacs. But their structure is so complicated as to require a minute description.

The two tentacles (Plate IV.), with their elongated cavity and the vertical tubes, which penetrate into the base of the sacs, constitute, indeed, most complicated pieces of

machinery, in which hydrostatic power, elastic levers, and muscular action give rise to highly complicated combinations and most diversified phenomena.

In the first place, the cavity itself from which each of the two tentacles issues (Plate IV. Fig. 1, 2, and 5) is a wide, elongated, pear-shaped sac, the rounded extremity of which is turned upwards and bent obliquely outwards, so that its convexity is turned towards the centre, and its blind sac upwards and outwards, and its open lower extremity downwards and outwards. In this cavity, to which the surrounding water has free access through the lower opening, the tentacle, with its complicated base, is attached by a broader surface to the inner side of its upper part. And though the central cavity of the body communicates freely, through the vertical tubes of the main horizontal trunk, with the base and curved hook of the tentacular apparatus, there is no free passage from one of the cavities into the other. The fluid which is injected into the vertical tubes runs back through the same channels into the main trunk, and the water which washes the central cavity of the tentacular apparatus empties through the same lower opening by which it is introduced. In a state of dilatation water penetrates from without into the pear-shaped sac, and chyle is injected from within into the vertical tubes; and in a state of contraction the chymiferous tubes are emptied at the same time that the water is pressed out. (Plate IV. Fig. 1, 2, and 5.) During these alternate contractions and dilatations, the tentacle itself may be coiled up in the cavity, or drawn out at full length, though in the most dilated state the threads generally hang out. But there seems to be also an antagonism, in a middle state of dilatation, between the filling of the vertical chymiferous tubes and the protrusion of the tentacle, the motions of which depend partly upon the muscular action of the apparatus to which it is attached, and partly upon the state of dilatation of the tubes on the inner surface of its base. The dilatation and contraction of the tentacular cavities depend upon the contraction and dilatation of the vertical bundles of muscular fibres of the two lateral zones, and more especially of the sphincters around their lower extremities; the sphincter reducing the diameter of the cavity, and shutting its opening, while the vertical bundle shortens and widens the whole cavity.

To form a correct idea of the ever-changing state of these parts, it is necessary to keep in mind their form and structure, as well as their relative position. The base from which the tentacle arises (Plate IV. Fig. 5) is an oblong disk encircled by elastic springs around its sides, which are bent inwards at its upper end, and turned outwards and downwards in the form of a hook projecting outside. The flat base of this disk forms the inner partition of the cavity in its upper part, and the vertical chymiferous tubes, which penetrate into the base of the tentacular apparatus, rise close together

and parallel to each other, at its lower margin diverging somewhat to reach the summit of the disk, but keeping nearly parallel between the marginal spring and its medial arch. From the summit the tubes also bend outwards and downwards, and terminate in blind sacs below the middle of the flat disk, so that, seen in profile, as in Plate III. Fig. 2, and Plate IV. Fig. 2, they appear like a tube terminating in a blind sac in the shape of a hook; but seen from the side of the animal, or by the broad surface of the disk, the curved termination of the tubes covers the upper portion of their ascending branches, as is seen in Fig. 5 of Plate III.

The action of the filling of this tube is, therefore, to project the whole apparatus into the tentacular cavity, and to stretch its upper hook outwards; the impulse to a retrograde movement of the fluid is probably derived from the elasticity of the spring encircling the flat disk, and especially from the pressure of its curved middle branch, aided perhaps by the action of a minute muscle, which descends obliquely from its lower extremity, and is attached to the inner wall. The figures of Plate IV. represent this apparatus seen in various positions, in order to make all its details as clear as possible; and in order fully to appreciate them, its position in the main cavity of the body should be contrasted with other figures illustrating the general arrangement of the circulatory tubes, as seen in Plate III., and especially the vertical tubes (Fig. 2 and 5) rising into the tentacular cavity. The base of this apparatus, being attached by its flat side to the inner wall of the cavity, appears in profile, in a front view of the animal, so that the flat disk is represented by a narrow margin, as in Fig. 2 of Plate IV., when its whole height is apparent. Seen from the sides of the animal, its width becomes distinct, and the elastic springs encircling its margin, and rising from the upper summit along the middle to form the external hook, are seen in face, as in Fig. 5 of Plate IV. Seen in half profile, or in a three-quarter view, both margins and hook become distinct, as in Fig. 1 of Plate IV.; and the tentacle which arises from the hook can be traced from its origin through the upper part of its course. In these three figures the whole height of the apparatus is equally apparent; but in Fig. 3 and 4 the cavity and apparatus are foreshortened, being seen from above in Fig. 3, and from below in Fig. 4. In Fig. 3 the curves of the springs in the upper margin are plainly visible, and the two tubes ascending along the inner wall appear like two holes. In Fig. 4 the origin of the tentacle is more particularly shown. In order to form a correct idea of the relations of the tentacle proper with the flat disk from which it arises, it is necessary to keep distinctly in view the arrangement of the springs encircling the disk. Whether these springs are a mere swollen margin of a membranous coat, or a fold of the inner wall of the cavity, or an organ of a peculiar tissue, I have not been able to ascertain. However, so much is certain,

that along the vertical chymiferous tubes which arise towards the upper end of the tentacular cavity, there are on each side linear edges slightly swollen in their middle, and thinner below, but curved over the middle of the disk from above, where they unite; then, descending somewhat lower, they are detached from the outer surface of the disk, to meet on their lower margin a similar fold rising from below, and then hang downwards into the bottle-shaped cavity free, as an independent thread, surrounded as soon as it is free from the disk by numerous small elastic and contractile tentacles. The main thread, however, forms the stem of the tentacle, which is capable of an extraordinary development, and can also be contracted into a coiled bundle; so that, in the state of utmost contraction, it forms a sort of irregular ball of tuberculated appearance hanging from the hook, the tubercles of the surface being the lateral fringes; but when elongated, it is changed into a fine thread, and the fringes appear at intervals, either in a contracted or elongated form, assuming, in the former state, the appearance of little tubercles, which in their elongated condition are themselves like so many little threads. In Fig. 1 and 5 of Plate IV., as well as in Fig 5 of Plate III., the tentacle being in its state of elongation, the lateral threads are distant from each other. Their arrangement in this part of the tentacle, however, is not easily ascertained; but when expanded, or regularly contracted within moderate limits, we cannot fail to see that they all arise from one side of the main thread, and are throughout unilateral. The variations which they undergo in their various degrees of contraction and expansion having already been described, when speaking of the movements of these animals, I need not refer to the subject again. I shall only mention that they appear frequently coiled up like a corkscrew in a regular and more or less elongated spiral. But, strange to say, in this position, though placed upon the two sides of the body in a symmetrical position, the spiral is not antitropic, but coiled in the same direction on both sides of the body, though their bases and hooks, and, indeed, the whole upper part of their structure, show a regular antitropic arrangement, like all symmetrical parts throughout the animal kingdom. Here, however, I have constantly found the spirals of the threads, when coiled up, curved in the same direction, both of them turning to the left in an ascending direction, or to the right in the opposite direction. This is the more surprising, as in animals in which there are parts twisted upon the two sides of the body, those of the right side are curled in one direction, and those of the left side are curled in the opposite direction, thus establishing perfect symmetry; and this law of nature is imitated in architectural ornaments, to produce complete symmetry. Thus, the horns of cattle, sheep, and goats are twisted, the right to the left, and the left to the right, while in antelopes the direction is reversed, the right horn being twisted to

the right, and the left horn to the left. The same is also the case with the bend of tusks in elephants and wild-boars, of the horns in deer, &c. Such an antagonism seems, therefore, not yet to prevail among Radiata, in which the anterior and posterior extremities have not become prominent.

Plate V. gives some further details of the structure of these tentacles. The main thread, a portion of which is represented in Fig. 1, consists of elongated muscular fibres, among which the nuclei of their primitive cells are sometimes still preserved, as seen in Fig. 8. The surface of the thread is covered by several layers of epithelial cells, among which, however, I have noticed no great differences in form and size, and I have also failed to discover lasso-cells among them, though these tentacles are endowed with an intense power of nettling, as they strike dead almost instantly any small Entomostraca which come within their reach.

As shown in Fig. 1, the lateral fringes arise uniformly from the same side, and where one is occasionally seen in a different position, it is easily ascertained that it is out of shape, owing to pressure when placed under the microscope. These lateral fringes have the same structure as the main thread, consisting of a bundle of elongated fibres in the middle surrounded by epithelial cells. The longitudinal fibres, however, extend into the main thread, where they appear like transverse fibres. There seem, however, to be no transverse fibres proper to any of the lateral fringes, nor even to the main thread, as, in every instance, I could trace those transverse fibres of the main thread into the centre of the lateral ones. The extension of the threads must, therefore, be of a more passive character, owing to the relaxation of the fibres, rather than produced by the contraction of annular fibres. The longitudinal fibres of the lateral fringes, however, may probably contribute in their contraction to the elongation of the main thread. This disposition explains very fully the slow elongation of the tentacles, in comparison with their quick and almost instantaneous contractions, and also the peculiar phenomenon attending this elongation, when, by starts, the main thread seems rather to be dropped from point to point to its fullest elongation, in a passive way, by the relaxation of the fibres. I am, however, at a loss to explain by their structure the elongation of the lateral threads at right angles with the main thread, when this is fully expanded, and their various dispositions, their frequent straight and apparently stiff elongation, and, still more, their sudden bending even in acute angles. These motions are so diversified, and sometimes so sudden, as to astonish even those familiar with the movements of these animals.

Having described above the position and changes of form of the digestive cavity, I have now only to add, that its inner surface has not throughout the same appearance, and is

not uniformly flat. Near the aperture of the mouth, indeed, it is smooth, and when the mouth is fully expanded a broad funnel is opened leading directly into the digestive cavity, assuming, however, in its contractions very diversified forms, being at times perfectly circular, and at other times oblong, oval, or even angular. The anterior and posterior angles of the mouth form frequently a fold, as in Fig. 5 of Plate IV. or in Fig. 2 of Plate II., and in Fig. 3, 4, 5, and 6 of Plate V.; or it assumes a linear shape, as in Fig. 7 of the same plate, or a stellate form, as in Fig. 5 and 11, Plate II. The more the mouth is open and spread out, the more easy it is to follow to a considerable depth the tubes which rise vertically along the walls of the stomach, as seen in Fig. 3 of Plate III., where they are slightly bent sideways to show their origin from the main transverse trunk below. The walls of the stomach lower down present four folds, two of which are in the direction of the fissure of the mouth, along the anterior and posterior walls of the stomach, and two others at right angles with them along the middle of its broader wall, in the plane of the transverse axis of the body. These four folds are lined with brown cells, and constitute probably a rudimentary liver, or at least secreting cells aiding in the process of digestion. Towards the lower extremity of the digestive sac, between those prominent folds, the walls of the digestive cavity are lined with a vibrating epithelium, which is particularly active round the lower opening of the sac, when this is fully open. This vibrating epithelium is continued upon the outer surface of the sac, and lines also, as already mentioned, the inner central cavity into which the stomach thus projects. (Plate III. Fig. 6 and 7.)

If we now view this animal from the opposite side, we find a variety of organs, the structure of which is not easily understood. Considering them at first chiefly in their forms, it will be seen that there is an elongated area, well circumscribed in its outlines, extending in a longitudinal direction in the same plane as the mouth, with a black speck in its centre (Fig. 4 of Plates II., III., and IV.). Towards the centre of this area eight narrow tubes are seen diverging (Fig. 4 of Plates III. and IV.), and in an oblique position two indistinct projections may be observed near the margin of the area. What all these parts are is not easily ascertained, and it is still more difficult to determine their connection with other organs. The black speck in the centre (Plate V. Fig. 9 and 10) rests upon a tubercle within, which is itself encircled by a tube; but the narrow longitudinal area is a membrane with a well-circumscribed and somewhat prominent margin, covering a hollow space. The irregular transverse bulbs at the base of its anterior and posterior halves, near the black speck, are the swollen extremities of two branches of the medial vertical funnel. And if we start from these facts, we may perhaps throw some

light upon the structure and functions of the whole apparatus. Let us, for this purpose, go back to a renewed consideration of the funnel itself. We have seen that it is simply a central, vertical, downward prolongation of the main central cavity, tapering gradually into a narrow neck (Plate III. Fig. 1 and 2); but before it reaches the lower surface, it enlarges again very suddenly, branching into two forks, which are themselves swollen into two irregular bulbs resting against the lower surface, one in front, and the other behind the central black speck, but both close to it, and partly encircling the tubercle upon which the black speck rests. These two bulbs are therefore simply dilatations of the forked lower extremity of the funnel, and we constantly see undigested matters accumulated in them and revolving in their cavity, with a tendency to accumulate laterally in an obliquely opposite direction in each of them. And at long intervals these prominent oblique angles will open (Plate V. Fig. 9), when the fecal matter within the bulbs is discharged, the aperture remaining for a longer or shorter time extended, and the vibrating cilia lining the inner surface playing very actively; but after a little while, these openings shut again.

These apertures might, therefore, be considered as a double anus; but I think it were a very injudicious comparison to homologize them with the anus of higher animals, for in this type the process of digestion and assimilation, and the circulation of the nutritive digested food, are carried on by means of apparatus widely different from what we observe in either Mollusca, Articulata, or Vertebrata. We have seen above, that the food is introduced into the digestive sac which hangs into the central cavity; that this sac opens freely into that cavity, and discharges there its contents, mixed with a large quantity of water; that this peculiar apparatus is subject to regular contractions, and circulates the fluid, with the nutritive parts suspended in it, into the various tubes branching through the whole system, and that gradually the refuse matters drop into the central vertical funnel, to be discharged below through the openings of the two hollow bulbs branching from its lower extremity. We have here, therefore, rather openings in the circulatory system than anal apertures, or rather, we have here an apparatus entirely different in its adaptation from either the alimentary canal or the circulatory system of higher animals, but constructed upon the same plan as similar apparatus in the class of Polypi and in other Medusæ, with only this difference, that in Polypi the digestive central sac empties its contents into a large cavity subdivided only with partitions, without definite circulatory tubes, but along which the fluids are nevertheless circulated up and down, and into the tentacles, and discharged either in a retrograde current through the stomach and mouth, or through the tentacles and lateral pores, when such exist. In Discoid Medusæ a similar circulation takes place, but without openings either in

the periphery or opposite the mouth; at least not in the Naked-eyed Medusæ, though the fluid discharged from the digestive cavity is circulated through tubes into the periphery and around it, and the refuse matters, retracing their course, are emptied through the mouth. Whether any Medusæ have peripheric openings through which the refuse matters are discharged, as Ehrenberg maintains, I have been unable to ascertain. However this may be, so much is plain, — that, in Medusæ and Polypi, the whole digestive apparatus is in direct broad communication with the circulatory apparatus; that the fluid circulated is simply chyme mixed with water, carried through all parts, which either retraces its course or is discharged through particular openings of the circulatory apparatus; and that there is no continuous alimentary canal with an anterior and posterior opening, and no distinct circulatory system deriving its fluid through lymphatics from the alimentary cavity, but two closely connected systems, one presiding chiefly over the function of digestion, and the other circulating the whole mass of digested food, that is, chyme mixed with water. It will, therefore, be more proper to call the upper sac the digestive sac, the central cavity with its branching tubes the chymiferous sac, and the vessels chymiferous vessels; and to consider the circulation, not as a blood-circulation, but as a chymous circulation, and, in some degree, the centres of this circulation, which act in antagonism to each other by their alternate contractions, as a sort of chymiferous heart.

If we next consider the oblong area and its cavity, I am able to state that the hollow space below, which extends forwards and backwards from the two cloacal bulbs, is a direct prolongation of the cavity of the bulbs, lined equally with vibrating cilia, and in which the fluid accumulated in the bulbs moves also to and fro. (Plate V. Fig. 9.) The ridge which circumscribes the outline of these tubular sacs is very definite, and slightly prominent upon the surface, though smooth. But in some Beroid Medusæ, such as the true Beroe, this ridge is slightly fringed, and it may be that these fringes constitute rudimentary gills, and that the marked outline of the area in our Pleurobrachia is a rudimentary development of such fringes.

The narrow tubes alluded to above, as converging towards the centre of the circumscribed area, can be traced from the lower extremity of the vertical rows of locomotive fringes to the immediate vicinity of the black speck in the centre of the lower end of the body. These tubes are direct prolongations of the vertical or ambulacral chymiferous tubes, tapering gradually towards the lower extremity of the animal, and extending beyond the rows of fringes proper, but reduced in their diameter so much as to appear now as very slender tubes converging from the lower summit of the locomotive fringes to the centre of the lower surface of the animal. These tubes are eight in

number, like the ambulacral tubes of which they are the continuation, and they converge two and two, being more closely brought together in pairs towards the black speck of the centre. (Plate V. Fig. 9.) In their respective position they differ somewhat; though rising from the four lateral ambulacra, they preserve a rather straight course from the summit of the rows of fringes to the centre of the area; the anterior and posterior ones, however, bend towards the elongated part of the area, and follow obliquely the course of its margin, thus contrasting in some degree with the lateral ones. How these tubes terminate I have not been able to ascertain in a direct manner, but am inclined to suppose that they empty into the lower bulbs of the funnel. The tubes are so fine, and the circulation beyond the main stem of the chymiferous system is so easily stopped as soon as the animal is not in the most favorable circumstances, and coarse materials in addition to pure homogeneous liquids are so unlikely to be forced into these narrow channels, as hardly to afford an opportunity to watch the direction of the current. Perhaps a comparison of the different arrangements of these tubes in various genera may lead to a more satisfactory result respecting this point of the circulation.

I am equally at a loss to account for the precise connection between all parts which may be seen around and above the central black speck (Plate V. Fig. 9 and 10). Even the nature of this organ is very problematical. In its appearance it resembles somewhat the marginal colored specks observed in Discoid Medusæ, and on that account has been viewed by some as an eye-speck; but by those who consider the so-called eye-specks of Medusæ as rudimentary auditory organs, it has been considered as an ear-speck. But notwithstanding the difference of opinion upon its functions, all naturalists who have examined Beroid Medusæ have identified the black speck, which occurs in a central position upon the extremity opposite the mouth, with similar specks occurring about the periphery of Discoid Medusæ. But in my opinion this comparison is not correct, and I am inclined to consider this organ or this speck as something similar to the central colored speck which occurs in the middle of the disk in Discoid Medusæ, and which is particularly distinct in young animals soon after they have been detached from the polyp-like stem upon which they grew, — as a remnant of the connection which exists between the mother stem and its progeny in those Medusæ which multiply by alternate generations. This homology cannot for the present be sustained by direct observation, since the embryology of Beroe is as yet entirely unknown. But I should not be at all surprised, if Beroe were found to be the free Medusa form of some Hydroid Polyp from which Medusa-buds have not yet been observed; for the analogy between this central speck and what might be called the remnant of an umbilical cord in Discoid Medusæ is far greater than may at first sight be supposed. Its position in the centre of the summit

of the chymiferous cavity is identical with the position of a similar peduncle observed most easily in young Sarsiæ soon after their separation from their Corynoid stem. The circumstance, that at this extremity the chymiferous cavity has two openings in Beroid Medusæ, does not institute between them and the common Discoid type a greater difference than exists between the star-fishes with a central anus and those which are deprived of this aperture, and cannot on that account be considered as establishing a radical difference between the structure and arrangement of the main systems of the body in the two families. On the contrary, the circumstance, that here eight tubes, probably in connection with the central cavity, diverge towards the periphery, to extend vertically along its walls, and gradually to enlarge along the sides, establishes a close resemblance between the ambulacral tubes of Beroe and the vertical chymiferous tubes of the naked-eyed Discophoræ. Again, the circumstance of their uniting to form a circular tube around the periphery may be compared to the circumstance of the ambulacral tubes meeting in the peripheric horizontal tubes arising from the main central chymiferous cavity. There are differences in the number of parts, and slight differences in the manner in which they are carried out in their adaptation; but, on the whole, the relations between the mouth and digestive cavity proper, the central embryonic tubercle, and the chymiferous tubes, are essentially the same in the Beroid Medusæ and the Discophoræ.

There are some further complications in the Beroid, which are not yet carried out in the Discoid Medusæ. We shall see that Bolina in this respect is even still more complicated than Pleurobrachia. But this no more changes the fundamental relations, than the complicated ramifications of Astrophyton change the relations of that genus to Ophiura. They are essentially the same. Above the black eye-speck in the natural position of Pleurobrachia, or below it in those Beroid Medusæ in which the anal extremity of the animal is turned upwards, as in Bolina, there is a tubercle or ganglion-like mass of larger size than the black speck itself, consisting of heterogeneous elements, which seems to be encircled by a tube some way or other connected with the eight narrow converging ambulacral tubes, on the anterior and posterior side of which are seen four smaller tubercles or swellings, between which arise two threads rapidly diverging forward and backward, and extending into the circumscribed area. I can offer only suggestions respecting these parts, and must leave it for future investigations to decide what they are in reality. I am, however, inclined to suppose that the circle at the base of the ganglion is a vascular or chymiferous ring, answering to the ring observed above the proboscis in Sarsia, and I expect it will be proved that the eight narrow tubes connected with the ambulacral tubes arise from this circle, or empty into it. The four swellings in advance of and behind the tubercle

are probably vascular dilatations of this ring, similar, in respect to the position where they occur, to the bulbs of the funnel and the two threads between them extending forwards and backwards are probably only outlines of the folds which form the circumscribed area. But there is no part of the structure of Pleurobrachia upon which I can be less positive than upon this point.

As for nerves which are said to arise from the ganglion connected with this black speck, I have been unable to make them out. I have seen numerous muscular or contractile fibres connected with the lower extremity of the chymiferous funnel; I have seen these fibres diverging from above the so-called ganglion, but have never been able to trace any one of them beyond the length which contractile fibres have: again, I have repeatedly seen these fibres in a state of contraction or relaxation, presenting so little regularity in their distribution, that for the present I think it were rather assuming to decide upon the disposition of the nervous system of Beroid Medusæ. I am even satisfied, from the descriptions published, that the eight converging narrow tubes, of which I find no mention in former authors, must have been probably mistaken for nervous threads by some; and when Professor Grant states that Beroe has eight nervous threads arising from a central ganglion, I suppose he alludes to the central black speck and its swollen base, and the eight narrow chymiferous tubes, the connection of which with the ambulacral tubes is so easily traced, though their central connection with the vertical funnel still remains doubtful. I do not, however, deny that this centre is a point where we have to look for at least one part of the nervous system, and the gelatinous lobes about the mouth for the other part, if there be really a distinct nervous system in Beroid, as in Discoid Medusæ. But, for my own part, I have failed in tracing it out; though I may add, that I am sufficiently acquainted with the structure of the region where it is said to have been observed, to doubt the accuracy of the statements which have been made about it, especially in the precision and distinctness with which it is mentioned. And I express these doubts, notwithstanding the doubts I have myself respecting the real nature of some organs around the central black speck, for the very reason that, after finding there more than has been seen and described, and various things which may answer the vague descriptions given, I do not in reality find what has been said to exist in that part of the animal. The points to which future investigations should be directed with particular care are especially the relation which the central black speck may have with the formation of Beroe as buds from Hydroid Polypi; next, the connection of the eight narrow tubes with the central funnel; and finally, a more thorough investigation of the tissues above the black speck and within the circumscribed area, and the apparent termination of the narrow tubes.

Although I have kept Beroe alive for a month during spring, I have never seen in any of them any thing like ovaries and spermaries, and have not even succeeded in ascertaining in what part of the body the organs of reproduction are developed. And I must confess that the descriptions published by various authors respecting the sexual apparatus of Beroe have not yet satisfied me of the correctness of their statements.

BOLINA.

THE genus Bolina was established in 1833 by Mertens, from two species, one of which was observed in the Pacific, and the other in Behring's Straits. The genus is characterized in a remarkable paper on Beroid Medusæ, published in the Transactions of the Imperial Academy of Sciences, in St. Petersburg, in the second volume of the sixth series. It is considered as distinguished from other genera of that family by the great development of the mantle lobes, and by the circumstance of its eight rows of locomotive fringes not extending beyond the body itself; and though this characteristic is not strictly correct, in as far as I shall be able to show that the ambulacral rows are not strictly circumscribed within their apparent limits, the genus itself is a very natural group, which ought to be generally acknowledged. It is difficult to give a correct idea even of the forms of these animals, as they assume constantly different aspects in their various movements, and in the different attitudes in which they must be considered. Having had an opportunity to examine at repeated intervals, and for a longer time, a new species of that genus, which I have kept alive for months, I shall attempt to give a more complete idea of its remarkable structure, which may throw some new light upon the organization of the whole family, and also upon the natural relations which exist between its different genera. I saw this new animal for the first time, with Mrs. Arnold, of New Bedford, who had preserved it alive for my examination, in December, 1848. I myself afterwards found large numbers of specimens, during the months of March and April, and even as late as June, in various parts of Boston Bay. Dr. A. A. Gould, however, had already noticed this species as an inhabitant of the shores of Massachusetts, in his Report on the Invertebrated Animals of that State, where he considers it, however, as identical with the Alcinoe vermicularis of Europe. But a close examination has satisfied me that it is neither identical with that species, nor even belongs to the genus Alcinoe, but constitutes the first Atlantic representative of the genus Bolina.*

* It is a remarkable circumstance, that the Atlantic shores of America should furnish, in lower latitudes, a species of that genus so similar to that which occurs in Behring's Straits; but this is only one of the

There is a very marked difference between this species and Bolina elegans of Mertens, in the form of its lateral auricles and in its color, which is not rosy, as in the species from the Pacific, but of a milky bluish-white, as in Bolina septentrionalis, with which it agrees in the form of its auricles, differing from it, however, in the less limited development of its longitudinal diameter, in the greater approximation of the two auricles of each side, and in the greater width of the mantle lobes, for which reason I have called this species Bolina alata.

It is a most delicate, transparent, and diffluent animal; so soft, that it readily decomposes under the least unfavorable circumstances. The admixture of a small proportion of fresh water in the bowls in which I used to preserve them caused not only their immediate death, but their almost instantaneous decomposition. All my efforts at preserving specimens in Goadby's liquor have entirely failed, and when, under identical circumstances, I succeeded in keeping for a long time specimens of Pleurobrachia rhododactyla, I failed in preserving specimens of Bolina alata longer than twenty-four hours. Again, this species being by no means so common as the Pleurobrachia, with which it is found promiscuously, I had to contend with great difficulties in my investigations of its structure. I nevertheless succeeded several times in injecting it with indigo, and though the injection soon caused the death of the animal and its decomposition, I have been able to trace the circulation for a sufficient time to follow the full course of the fluids within the body throughout all its parts; and being already acquainted minutely with the arrangement of the chymiferous tubes in Pleurobrachia, I was fully prepared to institute between the two genera a minute comparison, to ascertain their differences, and to recognize the homology of their structure. I was even able to trace the connection of all the parts of the chymiferous system more fully in Bolina than in Pleurobrachia, and to ascertain connections between its central and peripheric tubes which I failed to perceive in Pleurobrachia, in which these connections may, however, be wanting to some extent, as has already been mentioned above, when describing Pleurobrachia rhododactyla.

In order fully to understand the structure of Bolina alata, and the relations of its various parts, it is necessary first to have a precise idea of its external form, which it is by no means easy to acquire, even after repeated investigations. Like Pleurobrachia, the body of Bolina is more or less ovate, but in an inverse direction; for its greater diameter follows the plane of the corresponding organs in such a connection as to show

many instances which show that species on the opposite shores of this continent are adapted to the difference which exists in the climatic condition, and the different course of the isothermal lines on the eastern and western sides of the Old and New Worlds.

that the antero-posterior diameter is the longer, while it is the shorter in Pleurobrachia, and *vice versâ*, that the transverse diameter is the shorter, while it is the greater in Pleurobrachia. This inverse agreement between the natural relations of organs and external form is most satisfactorily ascertained, upon comparing the position and direction of the circumscribed area and of the tentacles, and we shall see hereafter that in every respect the proportions of the body with reference to their longitudinal and transverse development are reversed in the two genera. Before this contrast had been established, I was unable to trace the homology of parts between the two genera. Indeed, taking the general form as a guide, I began with comparing the two animals in a position in which I undertook to place their prominent diameters in the same relation, and thus arrived at the conclusion, that the tentacles, which are far less developed in Bolina, and issue from the margin of the mouth itself, were organs differing from the tentacles of Pleurobrachia, which I considered as a system entirely peculiar to that type of Beroe, while the tentacles of the type of Bolina appeared to me as a sort of fringes of the mouth. But the moment I placed the diameters of the two bodies in a position inverse to their length, all parts being placed in the same natural relation as far as they correspond by structure, their perfect homology throughout the system was at once established. And not only the correspondence and antagonism between the anal area and the tentacles, but also the minor details in the ramifications of the chymiferous system, agreed in every respect. The difficulty under which I had labored was precisely that of an artist attempting in a family picture to bring out the resemblance between two kindred faces, while contemplating one individual in profile, and the other in a front view, but believing their position to be the same. With this inverse relation between the homologous parts considered in their reference to form in the two genera Bolina and Pleurobrachia, there is a corresponding opposition between the natural positions of the two animals in the surrounding media. Pleurobrachia, as I have stated, swims naturally with the mouth upwards or forwards, and the anal area downwards or backwards; in Bolina the animal moves with the mouth downwards and the anal area upwards.

The position of the tentacles, their natural relations to the body when in motion, and the direction of the aperture through which they issue, were the chief sources of error which led me first to consider them as different apparatus; for in Pleurobrachia (Plate I.) they are turned downwards towards the anal apertures, while in Bolina (Plate VI.) they are turned downwards towards the oral aperture. But now we may ascertain the homological identity of these appendages, by placing these two animals in the same structural position. It will be easy to understand how, in accordance with the form and movements of the various members of the whole family, the tentacles may issue from different heights

of the vertical diameter upon the sides of the body, and, according to the direction of its movements, be bent either towards the mouth or towards the anus, and thus a foundation for their correct correspondence fairly introduced. Judging from the figures of Mertens, it even appears that in the same genus this direction may be reversed; for in Beroe cucumis the tentacles are bent, and issue in the direction of the anal aperture, as is also the case in B. compressa and B. octoptera, while in B. glandiformis it is the reverse. May not this circumstance, however, coincide with some other differences in the structure of those various species referred to Beroe, and indicate the propriety of separating them generically? Judging from Pleurobrachia when contrasted with Bolina and Cydippe, we might infer that the tentacles were more and more developed in proportion as they are removed from the mouth. But Leucothea shows that oral tentacles may be as extensively developed as those which issue from the sides of the body. It is further a question, which I am not, however, prepared to answer, how far the tentacles of Beroe may be homologized with either the tentacles around the mouth, or those around the disk, of Discoid Medusæ. From their connection with the chymiferous system, I should be inclined to view the complicated branched tentacles of Beroe as corresponding to the marginal tentacles of true Discoid Medusæ, rather than as answering to the fringed lobes which surround the oral aperture in so many of the latter. The position of these tentacles with reference to the mouth bears some resemblance to what is noticed in the position of the anus in the family of Echini, where the anus may open below very near the mouth, or about the margin, or even on the upper surface of the disk, directly opposite to the mouth, without interfering with the general homology of those parts.

After this digression, if we return to a more direct consideration of the form of Bolina, we find that it differs from Pleurobrachia in the extraordinary development of two lobes on its lower extremity (Plate VII. Fig. 1, 2, and 3), inclosing, when shut, the mouth and its appendages, and extending transversely to the antero-posterior diameter, one forwards and the other backwards, so that they contribute when expanded to increase the already prominent length of the longitudinal diameter, leaving a deep transverse fissure between them, at the bottom and centre of which the mouth is situated. The body thus shuts up by the alternate approximation and separation of two valve-like lobes, hanging downwards, placed one in advance and the other backwards, in a position precisely inverse to that of the valves of Acephala, which rest upon the sides of the body, and move laterally. In addition to these two large broad lobes, there are on each side two smaller ones, which arise from the main body at about the same height as the anterior and posterior lobes, but which are simple short, narrow auricles converging or diverging alternately, and thus shutting from the side, and above the great transverse fissure of the

animal. With the power which these animals enjoy of opening widely or shutting closely their anterior and posterior lobes by contraction and dilatation, bringing them alternately close together or stretching them forwards and backwards, the general appearance of the animal is constantly so completely changing, that it requires long acquaintance with them fully to appreciate the connection of all the parts in their different attitudes, and the influence of the movements of certain parts upon the position of others, and upon their functions. The activity of the circulation through the chymiferous tubes, and the position the main branches of the central cavity assume in these different changes of the general form, are constantly modified, as are also the width of the body and the power of its contractions. But in the same proportion that the extent of the longitudinal diameter is modified by the expansion and contraction of the anterior and posterior lobes, the height of the animal, compared to its width and length, is also constantly changing. If we add to this the diversity of images which are brought before us, when we watch these animals in their various movements, from different sides, facing alternately the longer or the shorter diameter, the sides, or the upper or lower surface, I venture to say that it is impossible to make correct descriptions, and to give true representations of such animals, unless they have been watched for a long time in a living state; for it is utterly impossible to examine their forms out of the water, as all parts then collapse, fall together, break in pieces, or dissolve into a shapeless mass. And, although I acknowledge the great interest of the descriptions published by travelling naturalists, making us acquainted with the great diversity of types of these remarkable animals all over the world, satisfactory illustrations cannot be expected from any quarters save those where able observers have resided for a long time, and the accounts of the generic and specific characters of most Medusæ must be considered as provisional, so long as they are not revised under favorable circumstances.

Viewed from above, that is to say, from the anal extremity, with the lobes contracted, Bolina appears very much like Pleurobrachia, assuming then the form of a slightly compressed sphere (Plate VII. Fig. 5); and were it not for the opposite direction of the circumscribed area, which runs in the longer diameter, while it is transverse to it in Pleurobrachia, the identity would be almost perfect. Seen from below, however, (Plate VII. Fig. 6,) even when the lobes are contracted, the difference is already marked, owing to the circumstance, that the vertical rows of locomotive fringes do not extend uniformly from one extremity of the animal to the other, the two ambulacra of the anterior and posterior lobes being much longer than those of the sides, which terminate at about half the height of the body.

Viewed in the same position with slightly opened lobes (Plate VI. Fig. 5), the

difference between the longitudinal and transverse diameter is already more marked. But what is more striking, a considerable portion of the body seems, still further, more elongated than its general outline, and the four lateral lobes, or auricles, appear as appendages to the anterior and posterior lobes. In proportion, however, as the larger lobes expand, the small lateral lobes are successively more and more detached from them, and their real connection with the sides of the main body begins to be apparent, as in Fig. 7, 8, and 9. In this position the greater length of the anterior and posterior ambulacra, and the shortness of the lateral ones, are quite apparent. In proportion as the anterior and posterior lobes are more and more stretched forwards and backwards, their sides assume a more pointed form, similar to the horns of a crescent, or rather to the blade of a tomahawk, and the whole body, from its diminutive size, appears like two tomahawks in miniature placed head to head in opposite symmetrical directions, without handles, the four short lateral appendages looking like two small sticks projecting through the eye of the head for an equal length on both sides.

Seen from below, in the same development of all parts, the general outlines do not differ materially from the view just described, excepting that the mouth is in sight in the centre, extending forwards and backwards in the same plane as the circumscribed area opposite, and the ambulacra appear only indistinctly through the mass. Fig. 6 of Plate VII. represents such a view. The body, however, is sometimes stretched in the longitudinal diameter to such a degree as to give its outline an irregular, oblong-square form (Plate VI. Fig. 10).

Viewed in profile, the body presents also two very distinct aspects when seen by the broad face or by the narrow face, or when examined from its anterior and posterior or from its lateral side. Facing the anterior or posterior end, the symmetry of the figure, as in Plate VII. Fig. 4, arises from the parity and symmetry of the right and left halves of the body; the two sides of the anterior and posterior lobes being perfectly symmetrical. But here, again, the outlines may differ greatly, in consequence of the expansion or contraction of the lobes, which may hang down and look almost straight, with the main mass of the body above, or spread laterally and assume a rounded form, like a broad apron suspended from the chest with projecting auricles or appendages about its point of insertion (Plate VI. Fig. 6). In this position the anterior or posterior pairs of ambulacra are seen in their fullest development, extending from the summit along the middle of the lobe to its lower margin, tapering gradually as the lobes grow thinner.

Seen from the sides, the symmetry of the figure arises from the perfect symmetry and equality between the anterior and posterior extremity of the body, and the outlines

may vary, as the two lobes are pressed nearer together or stretched apart to a greater or less extent. The modifications in this respect are almost endless, as also the manner in which the margins of the lobes fold over; for their lower margin may hang loosely down, as in Plate VII. Fig. 3, or it may bend inwards, curving itself in rounded or square outline, as in Fig. 2, reaching, also, over the sides, or stretching more flatly. In these various states of dilatation or contraction, the lobes may diverge from each other in all possible degrees; one may even overlap the other alternately, and thus reduce to the utmost the difference between the longitudinal and transverse axis, as in Fig. 1. The small lateral lobes, two in number on each side, may, in these various changes of form, assume also the most diversified positions; at times stretching straight downwards, at times arching upwards, at times hanging down, converging towards and even crossing each other; so that there is no end to the diversity of these aspects. I should say, however, that the motions of these lobes, especially those of the two large anterior and posterior lobes, are comparatively very slow and graceful; while those of the small lateral lobes are somewhat more brisk.

Seen from the sides, the pair of lateral ambulacra (Plate VII. Fig. 1 and 2) converge from the upper summit towards the base of the lateral lobes, and the anterior and posterior ambulacra of the same side appear in profile near the anterior and posterior margin, encircling in parallel curves the lateral ambulacra, but extending and gradually tapering all the way down to the lower margin of the lobes.

The whole animal progresses rather slowly, its movements being tremulous, like dancing in slow steps through the water, and now and then revolving upon itself. But we never see those quick, darting motions which characterize Pleurobrachia, nor any thing like the graceful curves of the tentacles following it like a comet's tail, for here the tentacles do not extend beyond the margin of the lobes. And the lobes themselves are an impediment to quick and graceful motion; for the anterior and posterior ones are disproportionate in size to the body. There is, however, an attitude in which the movements of this animal are exceedingly graceful. It is when the lateral lobes are fully expanded, and even recurved forwards and backwards, and so elongated as to appear like two flower-petals spreading in an opposite direction, and curving outwards. In this development the animal generally reverses its position, the mouth being turned upwards, and the lateral lobes also curved outwards, presenting their vibrating fringes in the utmost degree of activity, the whole animal resembling an open white flower, with two large and four small petals revolving slowly upon its peduncle, or changing its place in various directions. Fig. I. of Plate VIII. represents a specimen in such an attitude.

The ambulacra are so closely connected with the appearance of the whole animal and its movements, that we had better consider these first. As in all Beroid Medusæ, they constitute vertical rows of movable fringes, identical in structure in every respect, as far as it has been traced, with those of Pleurobrachia, the difference consisting mainly in their extent, the pairs which run along the anterior and posterior extremities of the body, and extend upon the two large lobes, being by far the longest, and also somewhat wider, their flapping combs tapering gradually towards the anal area, so that the ambulacra terminate in points at some distance from the central black speck. This is equally the case with the two pairs of lateral ambulacra, which, however, extend somewhat farther inwards, the tip of the eight ambulacra encircling an oblong area, the longer axis of which is in the same plane as the circumscribed anal area, which extends, however, far beyond forwards and backwards, between the rows of combs of the anterior and posterior pairs of ambulacra. Another peculiarity which distinguishes Bolina from Pleurobrachia, in the arrangement of this extremity of the body, is the circumstance that the body here is not simply rounded, but somewhat depressed along the longitudinal axis; so much so, that the two sides bulge sensibly above the level of the central speck, while the anterior and posterior extremities are on a level with it. The consequence of this form of the main gelatinous mass of the body is, that the upper extremity of the anterior and posterior ambulacra runs almost straight, while in the lateral ambulacra it is arched over the two rounded parallel ridges which inclose the circumscribed anal area. It is easily ascertained, that eight small tubes, similar to those observed in Pleurobrachia, extend beyond the upper extremity of the ambulacra towards the central black speck, or rather towards the bulb under it, and that they are the prolongation of the vertical ambulacral tubes of the chymiferous system. Below the main bulk of the body, along its sides, the ambulacra gradually taper also towards their lower extremity, and as soon as they reach the height of the dilatation of the lobes, the locomotive combs disappear, and the vascular tubes which accompany them can alone be traced farther. In the lateral ambulacra, however, these combs are reduced much sooner. The rows themselves taper also sooner, and terminate at the base of the small lateral lobes near their inner margin, for a considerable length above the lower extremity of the ambulacra of the large lobes. In the small lobes we trace, also, a narrow prolongation of the chymiferous tubes, which extend beyond the locomotive fringes. The course of these narrow tubes upon the lobes is very difficult to trace, and their connection with each other and with the central chymiferous cavity has been entirely overlooked by former observers, though there are, in the figures of Bolina elegans published by Mertens, indications that he noticed the outline of their convolutions. I shall first trace the course of these tubes

upon the larger lobes. As long as the tubes follow a straight course in the prolongation of the anterior and posterior ambulacra, they remain at the surface of the gelatinous mass, covered only by the epidermis beyond the ambulacra themselves. But as soon as they diverge towards the sides, and approach the lower margin, where they bend to take again an inward course, they penetrate deeper and deeper into the substance, across the whole thickness of the lobe itself, till they reappear upon its inner surface, where they are nearest to each other, then rise, diverging again, and following almost exactly the outline of the lateral margins of the lobes, along which they ascend towards their bases, rising higher than the lower termination of the ambulacral combs, as high as the bases of the short ambulacra, then converge again, bend downwards, and in a sinuous, winding course descend again towards the lower margin of the lobe, remaining nevertheless above the first lower comb, and converging from the two sides immediately in the medial line; so that there is a direct communication between the right and left ambulacral tube of the anterior and posterior pairs, passing in their course from the margin of the outer surface to the middle of the inner surface, first descending, then rising, then descending again in undulating lines, until they meet to form a central continuous channel. Such a connection between any of the tubes on the oral side of the ambulacral tubes has not been seen in Pleurobrachia; but, as I mentioned when describing the structure of that genus, I should not be at all surprised if it should be finally found that there is such a connection around the mouth, for there are vascular tubes following the walls of the digestive cavity which reach the margin of the mouth, along the folds of which I have repeatedly thought I saw something like tubes and a current; but though I could never satisfy myself completely upon this point, and though I have always been unable to trace the ambulacral tubes in Pleurobrachia beyond the oral termination of the locomotive combs themselves, the existence of such minute tubes in the substance about the mouth of Pleurobrachia is rendered very probable, since it is seen here that extensive, and, indeed, even large vessels wind their course in the lobes, and we shall presently see that there is a further communication between those of the larger lobes and those of the smaller lobes, as well as between them and those around the mouth, in its margin and in the tentacular apparatus, so that the circulation of fluid from one summit towards the other, and the recurring movement in the opposite direction, are fairly established by a direct course of tubes in Bolina, though the movement of fluid in these tubes takes place in a backward and forward direction, which therefore does not imply the possibility of a complete want of such communication in Pleurobrachia, where the circulation would be reduced to a forward and backward movement in the main trunk of the system. The ambulacra of the sides are reduced to a simple chymiferous tube as soon as they reach the base of the

lateral lobes, whence the tube continues in a very complicated course through the lobe and towards the mouth, and also towards the large lobe. First, the tube follows the inner margin of the small lobes, then turns round their obtuse points and retraces a parallel course in an oblique direction; but the base branches in such a way as to unite simultaneously with a tube extending along the margin of the mouth, and with another extending into the large lobe, or it may rather be said, that an anastomosis is established at the base of the small lobes, on their external margin, with the chymiferous system of the large lobes, as well as with that of the margin of the mouth. Fig. 3 of Plate VII., in which the inner surface of the anterior lobe is turned outwards for the whole extent of its margin, shows this connection most distinctly. The anastomosis with the large lobe is established through a tube which arises from the lower sinuosities of the inner convolution of the long ambulacral tube. The communication with the oral tube is more direct, and may be considered as a branch from the tube of the short ambulacra; indeed, both may be considered so, the anastomosis with the large lobe, as well as that with the mouth. But, in the first case, the communication with the tube of the long ambulacra is more indirect than it would be if it were placed in the course of its terminal sinuosities, where it forms frequent anastomoses; while the connection with the oral system is direct, through a tube which only bends at right angles upon itself. What is the meaning of these numerous anastomoses upon the inner surface of the large lobes I cannot tell. Are they of the character of the gills of Brachiopods and Ascidians, or are they something of a nature more peculiar to these animals? This remains to be investigated.

But so much is certain for the present, that the large lobes and the small lobes are not fully identical. The large lobes are a mass of the same gelatinous substance which constitutes the principal portion of the body; while the small lobes seem simply membranous, and are really hollow sacs, a kind of *diverticula* arising from a folding of the surface of the body at the lower extremity of the short ambulacra. These lobes are, indeed, a mere fold, and the direct prolongation of the short ambulacra in every respect, though they seem as completely different from the ambulacra as they are from the large lobes. However, upon close investigation of their structure (Pate VIII. Fig. 8), it is found that their margin is encircled by vibrating cilia, and that the ambulacral tube follows the base of those cilia all round the margin of the lobe, until the cilia of the lobe disappear in their turn, and the tube alone is continued, branching, as mentioned above, into the large lobe, as well as towards the margin of the mouth.

Upon these considerations, we may, therefore, view the small lobes as a simple modification of the lateral ambulacra, bent inwards in proportion as the great transverse

fissure which separates the two large lobes rises higher along the sides of the mouth, and thus introduces a loop in the lateral ambulacra, instead of a straight course, as on the sides; the vibratory cilia of the small lobes being modifications of the locomotive combs of the ambulacra proper, which would appear as long on this side as on the other, if they were stretched in the same manner, but which are here folded over in the shape of prominent auricles acting more directly and energetically as lateral oars.

If this view of the four small lobes is correct, we may consider the vertical branch or fork of the vascular tube below as the direct prolongation of the ambulacral tube proper, and the fork which diverges into the large lobes as the anastomotic fork, connecting the ambulacral tubes all round the body. The horizontal branches along the sides of the mouth should then be considered as the anastomotic branches between the two lateral ambulacral tubes of each side, and thus the circle would be made perfect.

There is a great interest connected with a further investigation of the vibratory cilia of the small lobes, in comparison with the locomotive combs of the ambulacra. For the former are so similar to common vibratory cilia, and the latter are so plainly a more advanced system of locomotive apparatus with a complicated structure, and both are morphologically so fully homologous, as to show that, in the series of natural developments, vibratory cilia are not absolutely a specific type of structure, but may constitute, in a gradual development, a natural link, connecting more complicated organs with the simplest fringes of structural cells. I entertain now so little doubt respecting such transitions, that I have not hesitated throughout these descriptions to consider the rows of vertical locomotive fringes as true ambulacra, though there is as great a difference between them and the ambulacra of Echinoderms, as there is between them and simple vibratory cilia. We are thus led to recognize through the whole type of Radiata a natural gradation in the structure of the organs through which currents of water are produced around the body, from the simplest combinations in Polypi to the most complicated apparatus in Echinoderms. In Polypi we have only vibratory cilia arising from structural cells over extensive surfaces of the whole body, while in Beroid Medusæ there are, in addition to such cilia, peculiar rows of fringes, which move by muscular action upon their bases, and in Echinoderms each fringe in the shape of an independent ambulacral type assumes as great a structural complication as the whole system taken together in Acalephæ. The ambulacral tubes in Echinoderms, and the aquiferous system with its vesicles in star-fishes, or the true ambulacral gills in Echini, seem to me, indeed, to bear the same relation to each other, as the fringes of the locomotive combs, with their basal muscles, in Beroid Medusæ, bear to the vertical ambulacral tubes.

If, from this review of the superficial ramifications of the chymiferous tubes, we

proceed to an investigation of their connection with the interior stems and the central cavity of the whole system, we find a very close resemblance in their arrangement to what has already been noticed in the genus Pleurobrachia; the chief difference between the two genera consisting in their peculiar termination and connections in the peripheric lobes. The centre of the chymiferous system constitutes in Bolina (Plate VIII. Fig. 2 and 9), as well as in Pleurobrachia, a vertical hollow axis, extending from the centre of the anal area down to the sides of the digestive cavity, being, however, not so spacious as in Pleurobrachia, while the digestive cavity itself is larger, extending nearer the central black speck, so that the funnel which branches towards the circumscribed area below the tubercle of the black speck is shorter, the main cavity from which the main trunk to the ambulacra arises being much narrower, and the tubes extending towards the margin of the mouth, along the lateral walls of the digestive cavity, being in the same proportion longer. But the general arrangement is identical. The differences exist only in the proportional development of the different parts of the whole system, as also in the curve of the ambulacral branches, which are more strongly bent upwards, instead of stretching horizontally across the gelatinous mass. Owing to the lesser development of the central cavity of this system, and the difficulty of preserving alive these animals after injecting colored liquid into the chymiferous sac, I have not succeeded in discovering a regular contraction between the right and left sides of the system. It may be, also, that the transverse diameter, being so much shorter in this genus than in Pleurobrachia, and the means of establishing a retrograde current from the periphery much more extensive, the circulation takes place through alternate dilatations and contractions of the whole body, causing an injection of the fluid in all directions, rather than by an alternate passage from one side into another; and for various reasons of analogy I incline rather to this view. In the Discoid Medusæ, we have an absolutely radiating circulation, and a movement simply to and fro from the centre to the periphery, and back throughout the whole system. In Pleurobrachia there is an alternation between right and left, with a prominent circulation to and fro. In Bolina, there is also a bilateral symmetry, but the radiating circulation seems to be recurring in itself through a complete circle, which arrangement would already approximate the Beroid Medusæ of the genus Bolina to the type of Echinoderms, though in a lower condition of the circulating system.

Whatever may be the value of these suggestions, so much is plain, — that the digestive cavity constitutes a capacious sac with a longitudinal mouth, the fissure of which opens in the same plane with the anal area, precisely as in Pleurobrachia, in a gelatinous, oblong disk, extending with its longer diameter flat between the anterior and posterior lobes (Plate VIII. Fig. 6). This disk is entirely surrounded by the large lobes when they are

shut, but it forms the lower outline of the body when the lobes are entirely open and fully spread. In this attitude the mouth is shut, but the lobes are wide open, to inclose any food that may come within reach; and whilst dropping fragments of oysters upon them, as they are generally turned mouth upwards, in this extreme state of dilatation, I have sometimes seen the lobes close upon such morsels to secure them, and afterwards the mouth expand and open within to swallow the food, the tentacles being alternately drawn out and retracted.

The visible outline of the digestive cavity changes most remarkably in these various operations. When the mouth is shut, and the digestive cavity is empty, the digestive sac is completely flattened and compressed in the direction of the longer diameter, rising like a tapering funnel towards the central chymiferous cavity above; that is to say, the fold of the digestive sac which is stretched between the antero-posterior angle of the mouth converges towards the upper extremity of the body, and the flattened walls are pressed upon each other. In this position, the vertical chymiferous tube runs downwards, and along the middle of the outer surface of the digestive cavity, and reaches, near the lateral margin of the mouth, the sac of the tentacles. But after food has been swallowed, and the mouth is contracted into a more sphincter-like shape, and the digestive cavity so much narrowed above its external fissure, that the cavity of the digestive sac appears like a loose bag widest about half its height, with prominent angles in advance and backwards, swollen also laterally, but tapering above and below. In such a state the vertical chymiferous tubes of the sides have a more curved and even sinuous course, in accordance with the position of the morsels of food within, and the upper end of the digestive sac opens freely into the central chymiferous cavity.

I have seen distinct indications of fibres in the walls of this sac. There are also marked vertical folds along its upper end, of a brownish color, darker than the transparent walls of the other parts of the sac. But I have failed to see distinctly the vibratory cilia of the upper opening, though there is a constant movement of the minute particles of digested food about the aperture of the digestive cavity leading into the chymiferous cavity.

As mentioned above, this central chymiferous cavity is not only shorter, but also narrower, in the genus Bolina than in Pleurobrachia, though the fibrous structure of its wall is much more distinct. It has also a somewhat different form, though the same disposition, its sides bulging simply outwards, instead of forming two distinct trunks for the branches to the ambulacral tubes, as in Pleurobrachia; so that the four main branches arise in pairs almost directly from the main cavity, the tubes of one side, however, at greater distances from each other than the two corresponding anterior, or the two cor-

responding posterior ones, owing, no doubt, to the lateral compression of the body. And from the wider space between the two main branches of one side arise again the vertical tubes, which descend along the digestive cavity, towards the base of the tentacles.

Again, the four main branches of ambulacral tubes, instead of stretching horizontally towards the ambulacra, are bent upwards, and then divide each into two branches, to provide the eight ambulacra with as many vertical ambulacral tubes. The consequence of this arrangement is, that the impulse of the liquid pressed into the ambulacral tubes is chiefly in one direction, the branches from the main cavity meeting the ambulacra near their upper termination, and not at about half their height, as in Pleurobrachia. So that the chief current, and, I may say, almost the only constant current, is downwards along the sides, following the ambulacra, and all the sinuosities of their tubes in their lower course through the great lobes, as well as through the lateral auricles; and a comparatively very small portion of fluid flows towards the upper centre, through the very thin tubes extending from the upper summit of the ambulacra towards the anal area. The main antagonism between the currents, therefore, is between the upper and lower extremities of the body, and by no means between the right and left side, and *vice versâ*. Whether, however, the retrograde movement takes place upwards, through the same tubes in which it has moved downwards, or whether the winding course of the narrow tubes in the lobes constitutes a kind of capillary system, through which the liquid passes from one side of the ambulacral tubes into the other, I am unable to decide. But I cannot help thinking that this long winding course of the ambulacral tubes, upon the inner surface of the large lobes, and along the margins of the auricles and mouth, contributes to a more extensive aeration of the chyme in circulation than the straighter course in the wider vessels of the whole system in Pleurobrachia. But perhaps the more active alternate contractions in Pleurobrachia compensate by their quicker movements for the deficient ramification of the tubes themselves, which is so extensive in Bolina.

Of the narrow tubes about the anal area, I shall have to speak again presently. I shall only add here, that the vertical tubes upon the sides of the digestive cavity enlarge near the middle of the lateral margins of the mouth into a small, bulb-like dilatation, from which a bunch of tentacles may be issued or retracted. But this bulb is by no means so complicated as the tentacular sac of Pleurobrachia. There is no flat disk with elastic springs, but simply two narrow tubes arising from the main cavity, a little outside of the tubes of the digestive cavity, and following its course to the tentacular bulb. As, on account of the lateral pressure, the tubes of the digestive cavity and those of the tentacular bulb are brought into close contact, they appear at first sight

to constitute a single cord on each side; but in reality that cord consists of three tubes running in the same direction, which, being close together, are very easily mistaken one for the other, and whose natural connections are still more difficult to ascertain, as the bulb of the tentacle exactly covers the termination of the tube, resting immediately upon the digestive cavity and extending to the margin of the mouth. But whenever, by an oblique movement of the margin of the mouth, or by the dilatation of the tube, one way or the other, out of the vertical direction, the superposition of the bulb of the stomachal tube is disturbed, it must be seen how the tube of the digestive cavity divides into two horizontal branches, extending in opposite directions along the lateral margin of the mouth forwards and backwards, at right angles with the tube from which they arise, so that a direct communication is here established between the peripheric course of the ambulacral tubes and the main central cavity, a communication which very likely gives passage to the recurrent fluid, which does not return through the same tubes in its course. As for the two small tubes which unite in the bulb of the tentacles, they arise from the same lateral bulging of the same cavity from which the lateral tube of the stomach originates, but they arise more vertically.

The greater simplicity of the tentacular bulb has reference, no doubt, to the shortness of the tentacles, and to the circumstance that they are not protruded to any length beyond the margin of the mouth, but simply extend in a winding course forwards and backwards along that margin, forming, when contracted, a compact bunch, and appearing, when expanded, like a disorderly brush of irregular curled threads tied together on one side.

The best position in which to study the ramifications of the tubes on the side of the digestive cavity along the outer margin of the mouth, and the position of the tentacular bulb still farther outward, is when the animal is turned mouth upwards, with its large lobes fully expanded, when the mouth appears like a narrow rim in the centre of the prominent gelatinous mass between the large lobes which constitute a sort of compressed isthmus between the antero-posterior extremity of the body, along the margin of which the horizontal tubes from the stomachal tube are seen to extend as far as the right margin of the lateral auricles, without entering into direct communication with the tubes of the tentacular bulb. See Plate VIII. Fig. 6.

The walls of the central chymiferous cavity, and the main trunks which arise from it, are distinctly fibrous, and may easily be seen to shorten or elongate, and enlarge or contract their cavity.

The funnel enlarges above into two distinct branches, forming two bulbs, as in Pleurobrachia, with oblique openings forwards and backwards, on the sides of the circum-

scribed area, and with the black speck in the centre. This black speck has also a distinct ring, and it has seemed to me almost evident tha this ring extends, in the form of narrow tubes, along the margin of the circumscribed area, and also that the eight narrow tubes converging from the summit of the ambulacral combs empty into this ring; and as the ring itself is a fold from the prolongation of the funnel into the cavity extending forwards and backwards under the circumscribed area, it would follow that these eight tubes communicate here with the central chymiferous cavity, as they communicate from below through the tube around the mouth, an arrangement which would complete the circulation, the main movement of which would seem to follow the ambulacra downwards, with a small eddy upwards towards the eye-speck, and with a main recurrent stream along the digestive cavity. I should add, that the relative position of the eight narrow tubes from the ambulacra, where converging towards the anal area, differs considerably between the different pairs, the two anterior and the two posterior ones being very near together, almost in the longitudinal axis; and the two tubes of the two lateral pairs being, on the contrary, as far apart from each other as they are from the anterior pairs. So that there seems to be only six tubes meeting the central funnel, when in reality the anterior and posterior are each double.

I have not succeeded in making out a distinct nervous system connected in any way with the central tubercle, though numerous fibres diverging in all directions may be seen in connection with the upper part of the funnel. But it has always seemed to me that they are rather muscular fibres than nervous threads, for they change their length, and are by no means so symmetrically arranged as might be expected in a nervous system in these animals, when we know its disposition in other types of the class. This region, however, and the periphery of the mouth, are the places to look for it. But notwithstanding all efforts, I confess I have failed in the search.

With regard to Pleurobrachia, I have already expressed my opinion respecting the organic nature of the central black speck, which presents precisely the same appearance in Bolina, and the same general relations with the surrounding parts right and left, forwards and backwards, and below. The bulb below seems to me really to be simply a central projection of the chymiferous cavity, the ring around it something like the ring of Sarsia around its central tubercle, and the eight narrow tubes diverging from the summit homologous to the four vertical tubes of the Naked-eyed Medusæ, the whole differing only by the presence of apertures through which the refuse matters are discharged from the chymiferous cavity.

The extraordinary transparency of the gelatinous mass, and the impossibility of preserving the animal after death in a contracted state, forbid the prospect of ever knowing

fully the arrangement of the contractile fibres throughout the body. The general arrangement is very probably the same as in Pleurobrachia; for in some dying specimens, I have seen, at some distance from the central black speck, eight points between the ambulacra, alternating with them, arranged, as in Pleurobrachia, in the form of an oval, which indicate probably the presence of as many vertical bundles of fibres running from the upper summit downwards, and regulating the movements of the lobes jointly with circular fibres, which are more easily detected, and occur in great numbers grouped together in bunches along the sides of the vertical rows of locomotive fringes in the space intervening between their combs, and extending brush-like horizontally into the substance, though diverging in each bundle. These fibres seem more powerful, and, at all events, far more distinct, than the vertical muscles, which I have never been able to trace in continuous rows. Some means might perhaps be found to preserve their bodies in such a way as to bring out the muscular fibres. It would, indeed, be very interesting to study their arrangement, especially with reference to the motions of the large lobes.

Though I have watched specimens of this species at short intervals through six successive months, from December to June, I have never succeeded in discovering the sexual system, not even in the most rudimentary state. Should it, however, be found to follow in its development the course of the ambulacral tubes, as reported by Wild, this fact would go far to show the homology, to which I have above alluded, between the ambulacral tubes of Beroid Medusæ, and the vertical chymiferous tubes of Naked-eyed Medusæ. The circumstance of my failing to trace the reproductive system after so long a search, may show how great difficulty these investigations are attended with, and how much remains to be done before the whole history of these animals is satisfactorily made out.

Of their embryonic development nothing at all is known; but from the character of the black specks, I would repeat what I have said of Pleurobrachia, that I suppose them to be developed from Hydroid Polypi.

I have observed a third Beroid Medusa on the shores of Massachusetts, in Edgartown harbour and at Nahant, belonging to the genus Idya, but it was under such circumstances that I could neither examine it carefully, nor have drawings of it made to my satisfaction. I may say, however, that this species, at least in the condition in which it was observed, is much smaller than any of those described before. I regret the more to have been prevented from making a minute investigation of it, as that genus is particularly remarkable for the lateral ramifications of the ambulacral tubes, and it would be very important to compare these ramifications with the radiating ramifications of the chymiferous tubes in Discoid Medusæ.

The extraordinary metamorphoses of star-fishes and Echini, which Professor Müller first observed, ought not to be neglected in the study of Beroid Medusæ; for the remarkable resemblance between the singular transparent frame which protects the growing embryo of the star-fish and the body of Beroid Medusæ cannot be overlooked by an attentive observer; and the fact, that the parts of that external frame present numeric combinations which are unusual among Echinoderms, but which correspond to those of the Beroid Medusæ, will be an inducement to institute, at some future day, a close comparison between their structure and that of the Beroids. The ciliated appendages which hang downwards in those animals resemble closely the vertical rows of locomotive fringes with their chymiferous tubes, as observed in Beroid Medusæ. And it is interesting to find hat in Echinoderms there is a metamorphosis going on in the embryo, recalling the structure of the inferior class of Acalephæ in a manner very similar to the analogy which exists between the embryos of Medusæ and Polypi. For whether we compare the Strobila in its earliest conditions, or the young buds of Hydroid Polypi when producing Medusæ, the analogy of this earliest state of development of Acalephæ with Polyps is unmistakable, and I have no doubt that the external frame of the young Asterias and Echini, which Professor Müller has so beautifully illustrated, will be found to bear the closest resemblance to the structure of Beroid Medusæ, as soon as an actual comparison can be instituted with reference to the analogy of their structure, which is far more difficult to trace from descriptions and figures, however accurate these may be; but Professor Müller's attention seems not to have been attracted by this remarkable analogy, which he might have traced so fully when studying these embryos. So much, however, may be said already, that the general arrangement of the ciliated lobes of Plutus corresponds to the ambulacral rows of Pleurobrachia and Bolina, and that the tubes which accompany them compare closely with the vertical chymiferous tubes of the same Medusæ. Notwithstanding my efforts to observe the various developments of Asterias, I have, up to this time, been able to trace their growth only in the peculiar forms first described by Sars.

EXPLANATION OF THE PLATES.

The genera Pleurobrachia and Bolina, though apparently closely allied, and differing chiefly in the development of gelatinous lobes in the genus Bolina which do not exist in Pleurobrachia, present peculiarities which require the most careful comparison in order fully to understand their true relations. It has appeared to me, on that account, very desirable to mark the different parts in both with corresponding letters, in order to prepare the reader for the closest comparison, and a true estimation of their different direction in the surrounding medium. The different bearing of the separate rays, the difference in length of their longitudinal and transverse diameters, the inverse position of the mouth in their normal attitude, the apparent transposition of the tentacles, which seem turned towards the circumscribed area in Pleurobrachia, while in Bolina they accompany the main cavity of the edge of the mouth, are so many features in their structure which cannot be fully appreciated in their respective differences, unless the different species are placed in an identical position when compared. I have, therefore, assigned definite numbers to the different rays or rows of combs and radiating tubes, and marked them with corresponding figures, so as to enable the reader to institute the comparison, either by inverting Pleurobrachia, mouth downwards, to give it the same position as that which is normal in Bolina, or inverting Bolina, mouth upwards, in order to compare it in the same attitude as that in which we usually observe Pleurobrachia when moving. But I may repeat what has already been mentioned above, that occasionally both species may be observed in an attitude the reverse of that which they usually assume.

Before remarking upon the figures which fill the plates accompanying this paper, it will facilitate such comparisons, and the understanding of the individual figures, if I proceed first with an explanation of the letters with which the different parts are marked, which are precisely the same for all the figures in both genera.

A, B. Gelatinous lobes encircling the mouth, so large in Bolina as to form the greater bulk of the body. The two lobes, as developed in Bolina, are opposed to each other in the axis of the plane of the circumscribed area and of the mouth, so that they open and shut against the extremities of the longitudinal fissure of the mouth.

a. The mouth. It assumes the most diversified outlines when shut or expanded in various ways.

b. The narrow tube of the anterior part of the alimentary cavity, being a sort of gizzard or special division of the alimentary canal corresponding to the anterior portion of its tract in other animals.

c. The lower division of the alimentary cavity, performing simultaneously the functions of a stomach and those of a colon; for upon its walls we observe brown hepatic cells, but at the same time there is at its bottom an opening, through which the substances which have been digested are emptied into the main cavity of the body, *d*. This whole digestive cavity hangs free in the main cavity, and is truly the analogue of the alimentary sac of Polypi, as observed in Actinia, and may also fairly be compared with the alimentary cavity of Echinoderms, especially with that of star-fishes; though here the sac may be closed, as it never is in our jelly-fishes, or may empty outside of the animal, while in our Medusæ it empties into the main cavity.

d. The main cavity of the body, in which the products of digestion are circulated, mingled with water. This cavity corresponds truly to the main cavity of Polypi, with this difference, that in Polypi there are only partitions dividing it off around the periphery, while in Medusæ the gelatinous mass of which the body consists fills, to a great extent, the inner space of the animal, and leaves only tubes for the peripheric circulation of the fluid contained in it. There is one vertical prolongation, *f*, of this main cavity, extending in the direction of the circumscribed area, and which branches into two forks, f', f'', at its termination. The other tubes arising from it are the two main chymiferous horizontal tubes, *e*, *e*, with their branches, *q*, *q*, and their eight terminal forks, *i*, *i*, which open into the vertical tubes, *v*, *v*. The tubes *r*, *r*, which follow the walls of the digestive cavity, arise also from it near the main horizontal trunks, and from these latter arise the tubes of the tentacular apparatus, *a*, *a*.

e, *e*. The main horizontal trunks of the chymiferous tube, from which arise the eight radiating branches.

f. The vertical, funnel-like prolongation of the main cavity of the body.

f', f''. The two forks of that funnel. It should be remarked that the direction of that fork is in the plane of the longest diameter of the circumscribed area, which is also the direction of the longitudinal diameter of the mouth.

g. The roots of the tentacle.

h, h^1, h^2. h designates the whole tentacular apparatus, with all its complicated parts, h^1 being the tentacular apparatus of one side, and h^2 the tentacular apparatus of the opposite side. And these numbers are appropriated to the same apparatus in every figure, whatever may be the position in which the animal is observed. It will be noticed that these tentacles are placed at right angles with the plane of the mouth and the circumscribed area.

i. The eight horizontal tubes of the chymiferous apparatus which reach the vertical tubes, following the vertical combs. In all the figures the horizontal tubes are numbered in the same way, beginning with No 1 and ending with No. 8. Number 1 is assigned to that tube which extends to the vertical comb in sight on the left hand when the mouth is turned upwards and the tentacular apparatus appears symmetrically on the right and on the left; so that i^1, i^2, i^3, i^4 are the four horizontal tubes of one half of the body, and i^5, i^6, i^7, i^8 are the four horizontal tubes of the opposite half. And if the view I have taken of the diameters of these animals is correct, that the longitudinal diameter of the mouth divides the body into symmetrical halves, one right and the other left, the tubes i^1 to i^4 are the tubes of the anterior half of the body, and the tubes i^5 to i^8 are the tubes of the posterior half, and the tubes i^2, i^1, i^8, i^7 are the tubes of the left side, and the tubes i^3 to i^6 are those of the right side, or *vice versâ*, as we can only establish these general relations between the different diameters without determining strictly which is the anterior and which is the posterior edge of the mouth. It is probable, however, that no distinction is intended in the structure of these animals, as they are capable of assuming inverse positions, mouth upwards and mouth downwards, in which case the edges of the mouth appear in an inverse position.

j indicates the cavity in which the tentacular apparatus is suspended, and to the inner wall of which it is attached. This cavity opens in j', and through this opening the tentacle may be extended; but it is also capable of such contraction as to be entirely withdrawn within the cavity *j*.

j'. Opening of the tentacular cavity, through which the tentacle is protruded.

k. The main stem of the tentacle from which the fringes arise.

k'. Fringes of the tentacles which arise uniformly upon the same side, the outside of the tentacle, so that they are stretched in opposite directions from the two sides. But this direction is constantly modified in the various attitudes and the various degrees of elongation of the tentacles, as these are capable of being twisted upon themselves; so that the fringes may appear as forming a spiral upon the main stems, or may be stretched in all possible directions, in their more or less extensive elongations. However, at the base they arise strictly in opposite directions.

l, *l*. The vertical combs of locomotive fringes, of which there are eight of uniform length in Pleurobrachia, but four longer and four shorter ones in Bolina. These vertical combs are numbered in the same manner as the horizontal tubes which open into the vertical tubes accompanying the combs, and these numbers correspond in the different figures, in the same manner as in the tubes; l^1 to l^4 being the combs of one extremity, and l^5 to l^8 those of the other extremity, and l^2, l^1, l^8, l^7 being the combs of one side, and l^3 to l^6 the combs of the other side. Upon close examination, it will be found that the short combs in Bolina correspond to l^1 and l^8 of one side, and to l^4 and l^5 of the opposite side, of Pleurobrachia; that is to say, the short combs on the right and on the left side of Bolina embrace respectively the tentacular apparatus of the right and of the left side.

m represents the muscular apparatus surrounding the mouth; *m* indicating the radiating fibres through the agency of which the mouth is opened, and m' the circular fibres which shut it.

n represents the main vertical muscular bundles, alternating with the vertical rows of combs. Towards the circumscribed area, these rows assume a more pennate arrangement, which is designated by the letter *t*. Other fibres also diverge around the opening of the cavity containing the tentacular apparatus, and form a sort of constrictor, *p*.

o. Pennate bundles of muscular fibres attached to the sides of the vertical rows of combs and penetrating more or less into the substance of the gelatinous mass.

p. Horizontal bundles of muscles extending between the vertical rows of combs and the main muscular bundles.

p'. Diverging fibres of the main muscular vertical bundles, forming a kind of sphincter around the tube leading into the cavity of the tentacular apparatus.

q. The main trunk from which the eight radiating chymiferous tubes arise. It should be noticed that these tubes are not strictly in the same horizontal plane, since their respective position varies more or less in the different contractions of the body, and those on one side are successively higher than those of the opposite side in the alternate contractions of the opposite halves of the body, which regulate the general circulation of the nutritive fluid.

r. The chymiferous tubes following the digestive cavity. They arise from the main horizontal tube, and extend to the margin of the mouth, following the middle of the flat surface of the digestive cavity.

s. Eight narrow tubular prolongations of the vertical chymiferous tubes, which taper at the summit of the vertical rows of locomotive combs, and extend towards the centre of the circumscribed area, where they empty into the vertical funnel of the main chymiferous cavity.

t. Prolongation of the main vertical bundles of muscular fibres towards the circumscribed area, which follow the course of the narrow prolongation of the vertical chymiferous tubes, diverging like pennate muscles.

u. Combs of locomotive fringes.

v. Vertical chymiferous tubes, which accompany on the inner surface the rows of locomotive combs.

v'. Areolar space upon the inner surface of the vertical chymiferous tubes, from which the eggs are probably developed.

w. Base of attachment of the locomotive combs, from which the isolated fringes arise, and to which the muscular fibres moving these fringes are attached.

x. Ganglion, probably of a nervous character.

y. Ganglion-like bodies, arising probably from the accumulation of granules in the contracted state of the vertical chymiferous tubes when the circluation has ceased.

z. Free granules moving in the vertical chymiferous tubes.

a. Chymiferous tubes of the tentacular apparatus.

a'. The opening through which the vertical chymiferous tubes of the tentacle open into the main horizontal chymiferous tubes between their main forks.

β. Swollen margin of the elongated disk from which the tentacles arise.

γ. Medial keel arising from the summit of the elongated disk of the tentacle, and extending to the base of the tentacle itself.

δ. Eye-speck in the centre of the circumscribed area.

ϵ. Circumscribed area.

ϵ'. Raised line following the inner outline of the circumscribed area, probably the analogue of that row of fringes so conspicuous within the circumscribed area in some other genera of Beroid Medusæ, and particularly distinct in the genus Idya.

ϵ''. Another line parallel to the former, and within it, the special nature of which I have failed to ascertain.

ζ. The openings of the two bulbs of the vertical funnel through which the fecal matters are occasionally discharged.

η. Revolving bulb of fecal matter.

θ. The tubercle upon which the eye-speck, δ, rests.

ι, κ. Concentric swellings connected with the ganglion of the eye-speck, stretching in the direction of the longitudinal diameter of the circumscribed area.

λ. Four ganglionic swellings within the inner of the swollen margins near the ganglion of the eye-speck, the nature of which I have also failed to determine.

μ. Longitudinal muscular fibres of the main thread of the tentacle.

ν. Longitudinal fibres of the fringes arising from the sides of the tentacle extending across the main thread, where they appear as transverse fibres.

ξ. Coating of heterogeneous cells all round the main thread and its lateral fringes. The larger ovate cells are lasso-cells.

π. Prolongation of the vertical chymiferous tubes extending from the oral extremity of the short rows of locomotive combs to the auricles, and following the inner margin of the latter.

π'. The returning tube following the outer margin of the auricles, and anastomosing with tubes from the inner surface of the large lobes, ϕ, and also with tubes, v, arising from the margin of the mouth.

ρ. Prolongation of the vertical chymiferous tubes, extending from the anal extremity of the long vertical rows of locomotive combs upon the outer surface of the large lobes.

ρ'. The same tubes turning upwards and inwards.

σ. The prolongation of the same tubes upon the inner surface of the large lobe, winding again in an opposite direction, and forming several sigmoid curves.

τ. The extremity of the same tubes extending again downwards parallel with the corresponding tube of the opposite side, both meeting upon the median line in τ'. From these tubes arises a network of tubes, forming more or less rectangular meshes, — perhaps a sort of gill, ω, from which arises a recurrent tube, ϕ.

v. Tubes arising along the margin of the mouth from the vertical chymiferous tubes, r, which accompany the main digestive cavity.

ϕ. Recurrent tube arising from the margin of the internal network of vessels which spreads over the inner surface of the large lobes. This tube, following a course parallel to the edge of the large lobes, anastomoses near the base of the auricles with the recurrent chymiferous tubes, π, of the auricles, and the tubes, v, from the margin of the mouth.

χ. Auricles, four in number, corresponding to the short vertical rows of locomotive fringes, and therefore analogous to the vertical rows l^1, l^8, l^4, l^5. In accordance with this correspondence, the auricles are respectively marked $\chi^1, \chi^8, \chi^4, \chi^5$.

ψ. Vibratile ciliæ along the auricles.

ω. Vascular network upon the inner surface of the large lobes.

Plate I. — Various Attitudes of Pleurobrachia.

Fig. 1. A specimen in a state of rest, the tentacles hanging loosely downwards partly expanded, partly contracted into irregular tubercles; the fringes not expanded. The position of the specimen is such as to correspond to Fig. 3 of Plate II.

Fig. 2. A specimen with the body in nearly the same position, but bending obliquely forwards, the tentacles fully out, the fringes also expanded, except those near the base of one of the tentacles, which are partly contracted.

Fig. 3. A view similar to that of Fig. 1; the body, however, slightly turned upon the corresponding vertical axis, so that the three posterior vertical rows of locomotive fringes, which are not observable in Fig. 1, appear through the transparent gelatinous mass.

Fig. 4. Another view, in which the body has the position of Fig. 1 in Plate II.; one of the tentacles is contracted, the other fully expanded.

Fig. 5. View from the oral side of the body, corresponding to Fig. 5 of Plate II. The tentacles fully expanded.

Fig. 6. A view similar to that of Fig. 1; the body, however, very much elongated, moving forwards, the tentacles fully expanded.

Fig. 7. A view of the animal with the body also elongated, moving horizontally, the profile corresponding to that of Fig. 4; the tentacles stretching at right angles; one with all the fringes out, bending upon itself, while the other is partly contracted, with only a few of the fringes expanded.

Fig. 8. A specimen with the body horizontal, the tentacles considerably expanded. This figure corresponds to Fig. 7, where the elongation of the body has ceased.

Fig. 9. A view of the animal nearly in the same attitude as in Fig. 1, but slightly turned more upon its vertical axis. The tentacles slightly expanded; the fringes drawn in, the extremity of one of the tentacles coiled upon itself.

Fig. 10. A view from the side opposite to the mouth; the circumscribed area in the centre, but somewhat bent upwards, in order to show the branches of all the horizontal chymiferous tubes. The tentacles are in the utmost state of elongation.

Fig. 11. An oblique view, partly profile, partly from the side of the mouth. The parts in sight correspond to Fig. 2, only in an inverse position ; the tentacles moderately expanded.

Fig. 12. A specimen moving downwards. The organs in sight correspond to Fig. 3, but in an inverse position ; the tentacles slightly expanded, one of them coiled upon itself for some length, with a few fringes expanded.

Plate II.

Fig. 1. *Pleurobrachia rhododactyla* in a vertical position, the main cavity and the digestive cavity in sight from its narrow surface, and the tentacular apparatus right and left. Fig. 5 gives a view, from the side of the mouth, of all parts in the same respective position; and Fig. 4, another view from the opposite side, where the circumscribed area is seen in the centre.

Fig. 2 represents the same in profile, but in a position at right angles with that of Fig. 1, so that the main cavity of the body is seen from its broad surface, and one of the two tentacular apparatus in the centre of the figure. To bring Fig. 4 and 5 to agree in position with Fig. 2, they should be moved 90° upon their axes.

Fig. 3 gives another profile view intermediate between that of Fig. 1 and that of Fig. 2; so that the two tentacular apparatus are in sight, but in an oblique position forwards and backwards, and not right and left, as in Fig. 1, or in the centre, as in Fig. 2.

Fig. 4, 5. To bring Fig. 4 and 5 into the same position, they should be turned 45° upon their axes.

Fig. 6. A part of one of the vertical rows of locomotive combs, behind which is seen the vertical chymiferous tube, into which opens one of the horizontal radiating tubes.

Fig. 7. A portion of one of the vertical chymiferous tubes, the fringes of the locomotive combs being removed to show the bases of the latter, and the ganglia behind them.

Fig. 8 represents half the width of a vertical chymiferous tube, with muscular fibres behind it, and the granules circulating in its cavity.

Fig. 9 represents a portion of a vertical chymiferous tube similar to that of Fig. 7; but the tube is more contracted, and its walls so folded longitudinally as to present distinctly several parallel waving lines, which have no existence in reality when the tubes are fully expanded, but appear only when the tubes are separated from the body, and empty. The same lines appear also in Fig. 7.

Fig. 10. The mouth widely open, with the muscles which open and shut it around.

Fig. 11. The mouth when fully shut.

Plate III.

Various figures to show the course of the chymiferous tubes, the relations between the alimentary cavity and the main cavity of the body, and the connection of the tentacular apparatus with the chymiferous tubes. To render the figures more distinct, the fringes of the vertical rows of the locomotive combs have been omitted. The chymiferous tubes and the main cavity of the body are shaded. In Fig. 6 and 7, however, the shaded parts represent the digestive cavity.

Fig. 1. Corresponding in position to Fig. 2 of Plate II., and showing the connection of the four vertical chymiferous tubes of one side with the main horizontal chymiferous tube, the vertical funnel, the tentacular apparatus, and the vertical chymiferous digestive cavity.

Fig. 2. Corresponding in position to Fig. 1 of Plate II., and therefore placed in a position at right angles with that of Fig. 1, to show the relations of the chymiferous tubes and the main cavity in that position.

Fig. 3. The same parts seen from the side of the circumscribed area.

Fig. 4. The same parts seen from the side of the mouth.

Fig. 5. The tentacular apparatus in its cavity, to show the origin of the tentacle and the connection of the vertical chymiferous tubes of the tentacle with the main horizontal tube, and its branching forks.

Fig. 6. The digestive cavity entirely empty, and flattened in the position of Fig. 2.

Fig. 7. The same cavity, more expanded. In *c*, the brown cells at the lower extremity of the cavity give its surface a peculiar appearance.

Fig. 8. The vertical chymiferous tubes of the tentacular apparatus, in their connection with the main cavity, the horizontal tubes, and the funnel, are represented in an ideal outline, without any part of the tentacles themselves.

Fig. 9. One bulb of the vertical funnel seen from its narrow side, to show a ball of fecal matter accumulating near the opening of that cavity.

Plate IV.

This plate represents the general appearance of the body of Pleurobrachia enlarged and in various attitudes, and gives also several longitudinal and transverse sections of the body, to bring out more fully the relations between the different parts.

Fig. 1 represents the animal in the same position as Fig. 3 of Plate II.

Fig. 2 shows the animal in the same position as Fig. 1 of Plate II.

Fig. 3 represents it in the same position as Fig. 5 of Plate II.

Fig. 4 represents it in the same position as Fig. 4 of Plate II.

Fig. 5 represents it in the same position as Fig. 2 of Plate II.

Fig. 6 and 7. These transverse sections correspond to the line A B of Fig. 2, which letters (in this figure) have no reference to the lobes of Bolina and the swellings around the mouth of Pleurobrachia, marked also A and B.

Fig. 8 represents a vertical section in the position of Fig. 2.

In all these figures the cavities shaded with black lines are the chymiferous cavities and chymiferous tubes. The main stems are cross-barred wherever they are cut, in the section, and the openings of the chymiferous tubes are also cross-barred. The cavity of the tentacular apparatus is marked in addition by lines of dots. On contrasting Fig. 6 with Fig. 7, it will be perceived that Fig. 6 corresponds to a section across Fig. 2 at A, passing through the upper part of the tentacular apparatus; so that the tentacular cavity forms a crescent-shaped opening around the tentacular apparatus. The lower part of the cavity is marked by dotted lines, as are also the horizontal radiating tubes seen below. In Fig. 7, which is a section corresponding to B of Fig. 2, the lower part of the tentacular cavity is laid open at a point where it is occupied internally only by the tentacle itself, and all the radiating tubes and the fringe of the vertical funnel are in sight. In Fig. 8, the digestive cavity and the main cavity of the body, and the whole tentacular apparatus, are laid open by a vertical section, and the position which the tentacular apparatus holds within its cavity is fully displayed.

Plate V.

This plate represents various structural details of Pleurobrachia more highly enlarged.

Fig. 1. Part of a tentacle contracted, and the fringes arising from one side. The two fringes on the opposite side are simply displaced by pressure.

Fig. 2 represents the structure of the tissue under the vertical chymiferous tubes, where it consists of large, irregular cells, probably an ovary.

Fig. 3, 4, 5, 6 represent the mouth in various degrees of dilatation, assuming different forms, sometimes quite irregular, as in Fig. 3 and 4; sometimes elongated, as in Fig. 5; sometimes funnel-shaped, as in Fig. 6.

Fig. 7. The mouth in this figure is entirely shut, assuming a longitudinal form, which, in its direction, corresponds to the direction of the circumscribed area.

Fig. 8 represents a small portion of a tentacle greatly enlarged, to show the structure of the main stem and that of the fringes.

Fig. 9 represents the circumscribed area, the bulb of the eye-speck, and the two bulb-like dilatations of the vertical funnel.

Fig. 10 represents the bulb of the eye-speck, and the surrounding parts still more enlarged.

Plate VI.

Various attitudes of *Bolina alata* of the natural size.

Fig. 1 shows the animal as seen in profile. The two lobes, which are entirely shut, appear on the right and left.

Fig. 2 gives a view from above, with the same position of the parts, the lobes, however, projecting a little more, and the auricles crossing each other.

Fig. 3. A view of the same from below, corresponding, in the arrangement of these parts, to Fig. 2.

Fig. 4. A profile view of the animal in the same attitude as in Fig. 1, but with the lobes opening.

Fig. 5. A view from above, in the same position as that shown in Fig. 2, but with the lobes expanding in the direction of the auricles, so that the longitudinal diameter is less when compared to that in Fig. 2.

Fig. 6. A profile view in a position at right angles with that of Fig. 1 and 4 ; so that one of the lobes is in sight, with its broad outer surface, and the four auricles appear as projections in two pairs on the right and left.

Fig. 7. A view from above, in the position of Fig. 2 and 5 ; but the lobes are expanded, and the auricles are stretching in parallel directions.

Fig. 8 represents the same as seen from below, also in the same position as that shown in Fig. 3, but with the lobes open ; so that the mouth is entirely uncovered.

Fig. 9 gives a view of a specimen in the same position as that shown in Fig. 7, the lobes, however, still more elongated ; so that the longitudinal diameter of the animal exceeds by far the transverse diameter.

Fig. 10 represents the same from below.

On comparing all the figures in this plate, we have Fig. 1 and 4 in the same attitudes, differing only in the degree of expansion of the lobes. We have Fig. 2, 5, 7, and 9, views from above, differing, also, chiefly in the degree of expansion of the lobes. Fig. 3, 8, and 10 are views from below, facing the mouth, differing also in the degree of expansion of the lobes. While Fig. 6 represents a profile view, in a direction at right angles with that shown in Fig. 1 and 4.

Plate VII.

Enlarged figures of *Bolina alata*, in various attitudes.

Fig. 1. Corresponding to Fig. 1 of Plate VI.

Fig. 2. Corresponding to Fig. 4 of Plate VI.

Fig. 3. In the same attitude, the lobes still more expanded, and turned inside out.

Fig. 4. Corresponding to Fig 6 of Plate VI.

Fig. 5. A view from below, corresponding to Fig. 3 of Plate VI., the lobes, however, being farther open, so as to entirely uncover the mouth.

Fig. 6. Corresponding to Fig. 2 of Plate VI.

Fig. 7 gives an enlarged view of the horizontal chymiferous tubes, and their connection with the vertical funnel below the circumscribed area and the bulb of the eye-speck.

Plate VIII.

Fig. 1. A profile view of *Bolina alata*, in the same position as that given in Fig. 3 of Plate VII., but more elongated, and turned mouth upwards.

Fig. 2. A view of the main chymiferous cavity, to show its connection with the radiating tubes, the vertical funnel, and the tentacular apparatus.

Fig. 3. A highly magnified view of the vertical funnel and the bulb of the eye-speck, with the base of the radiating tubes.

Fig. 4. The base of the tentacular apparatus in its connection with the walls of the mouth ; seen in profile.

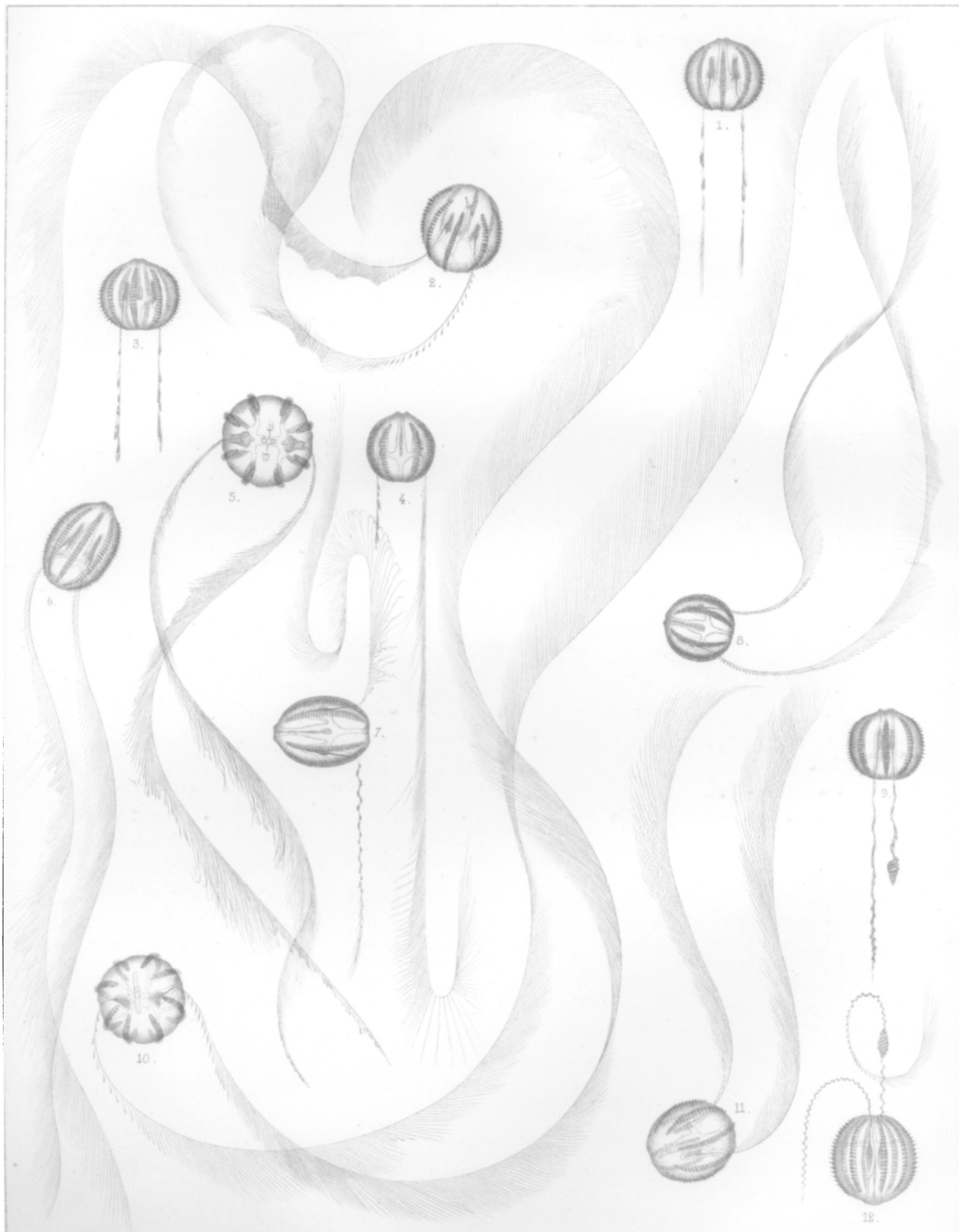
Fig. 5. A similar view, the specimen, however, placed obliquely, to show the two parallel edges of the mouth.

Fig. 6. A view of the mouth from below, with the chymiferous tubes following its edge between the fissure of the mouth and the tentacular apparatus, and anastomosing with the chymiferous tube of the auricle.

Fig. 7. An enlarged view from above, corresponding to Fig. 7 of Plate VI.

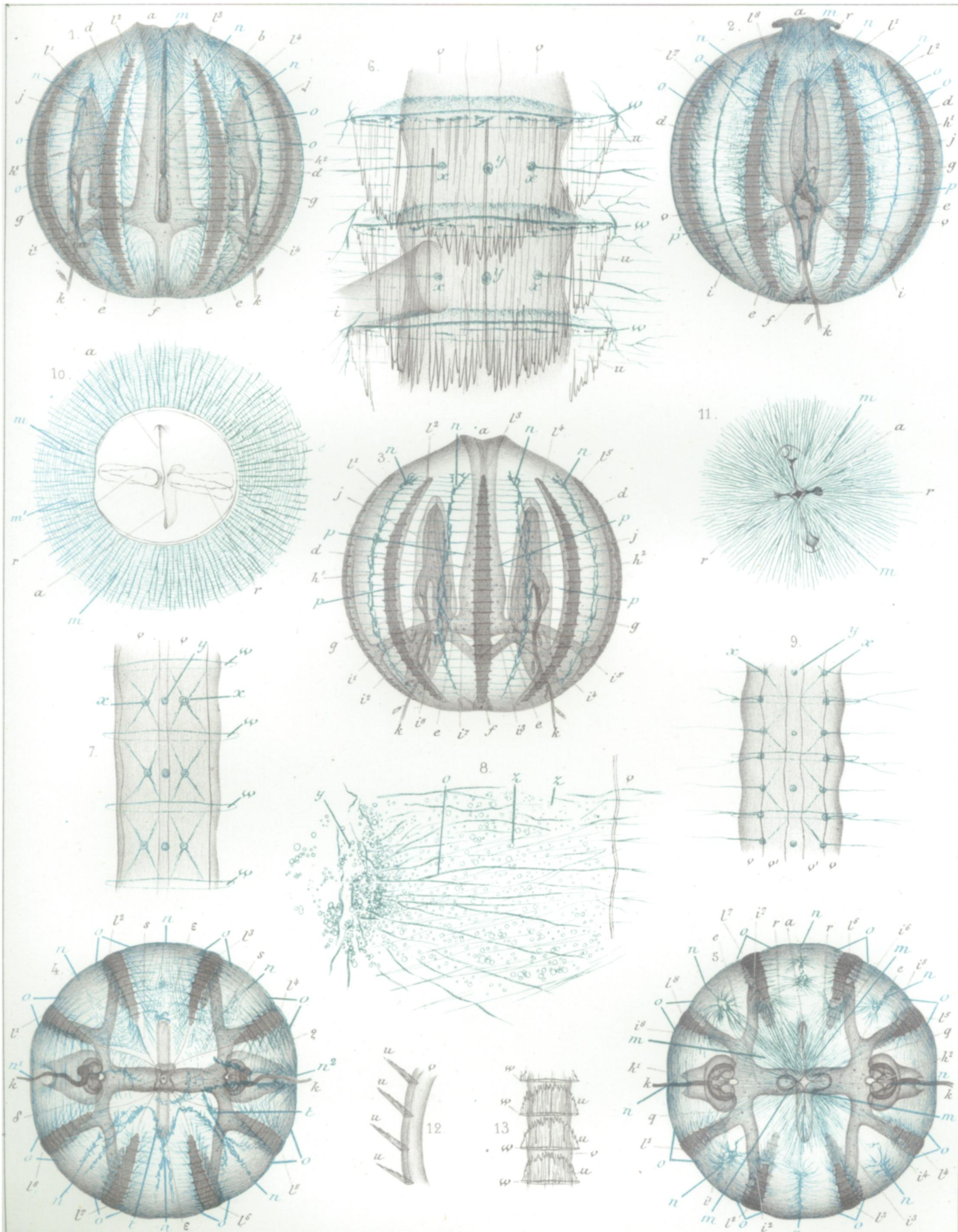
Fig. 8. The auricles greatly enlarged, to show the prolongation of the chymiferous tubes, which wind their course along through the margin of the auricles, to form an anastomosis with the chymiferous tubes from the large lobe, and from the mouth.

Fig. 9. A general view of the main stems of all the chymiferous tubes, seen from above, where the horizontal radiating tubes are most prominent; the tubes of the tentacular apparatus and the walls of the cavity appearing upon the sides of the bulb of the eye-speck, and the tubes which encircle the mouth being seen faintly through the substance of the body.



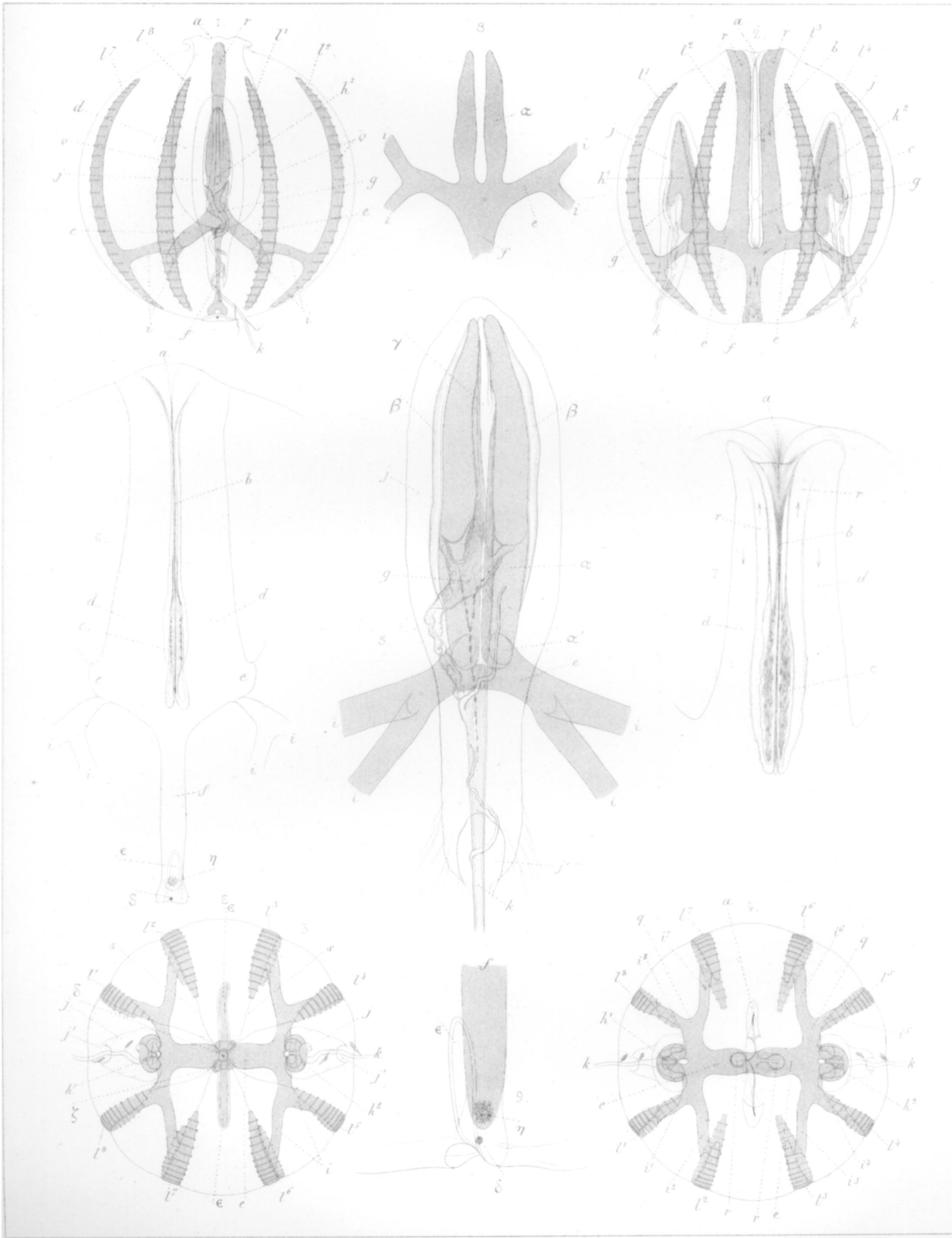
A. Sonrel on stone from nat. Tappan & Bradford's lith.

PLEUROBRACHIA RHODODACTYLA. Agass.



A. Sonrel on stone from nat. Tappan & Bradford's lith.

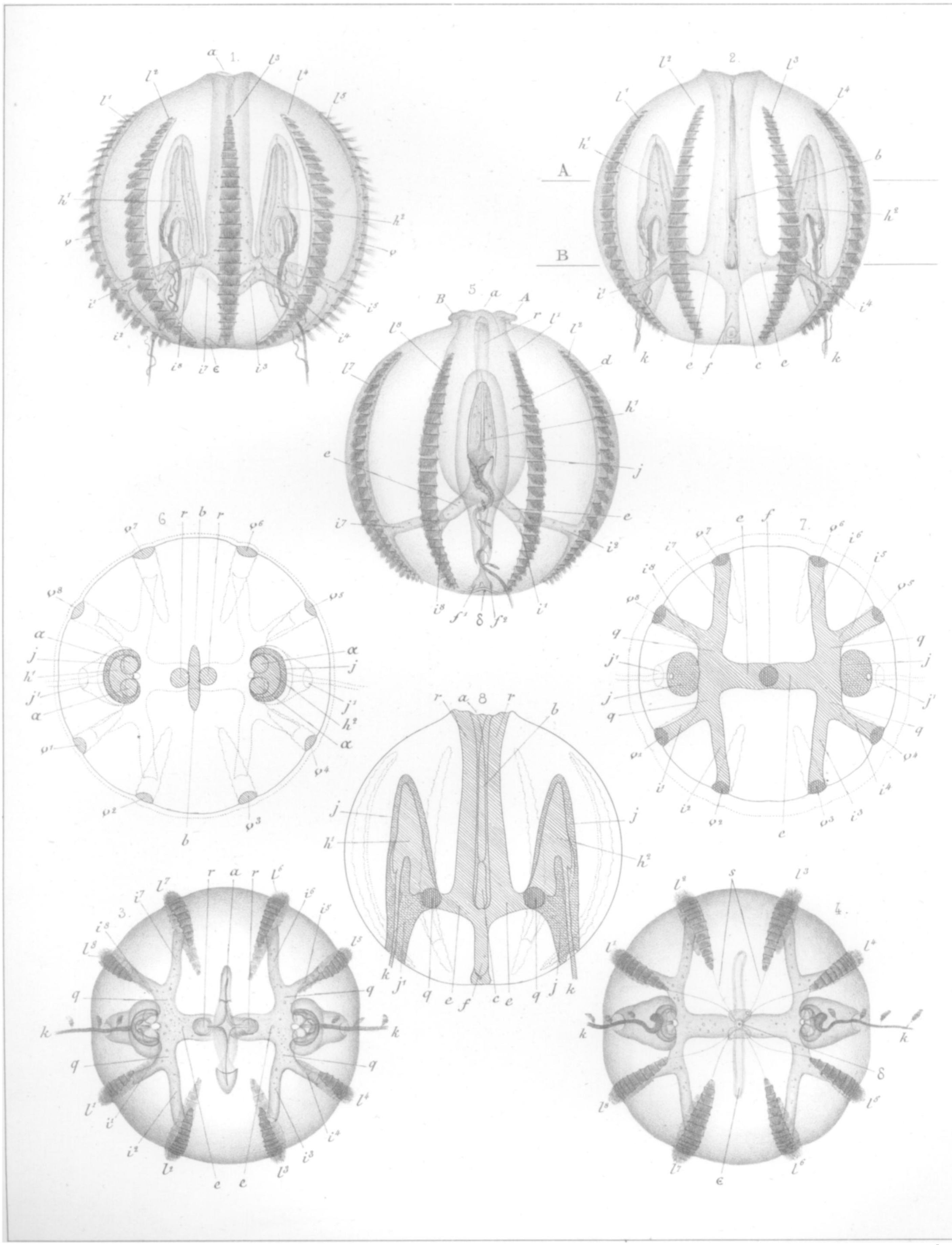
PLEUROBRACHIA RHODODACTYLA Agass.



A. Sonrel on stone from nat.

Tappan & Bradford's lith.

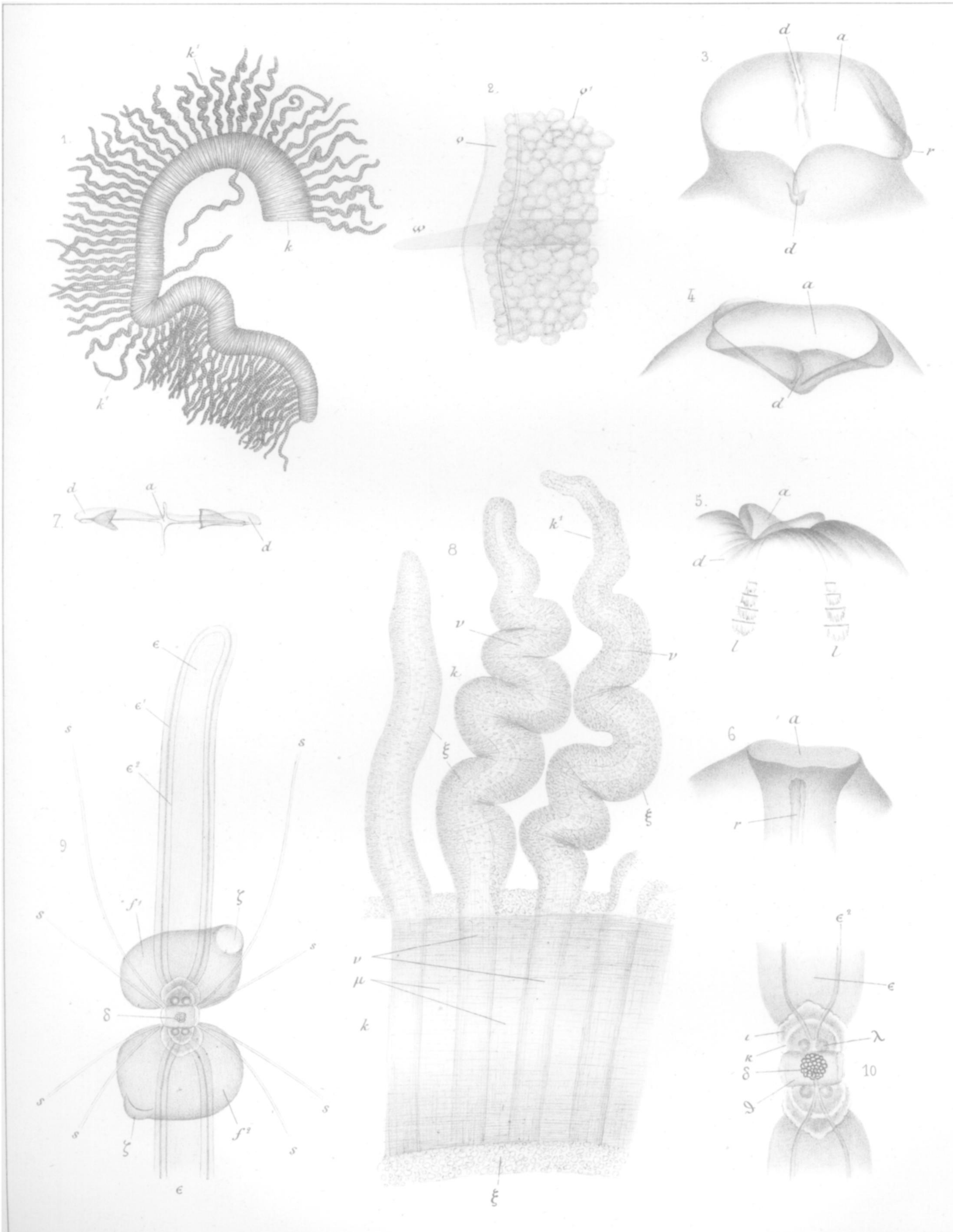
PLEUROBRACHIA RHODODACTYLA. Agass.



A. Sonrel on stone from nat:

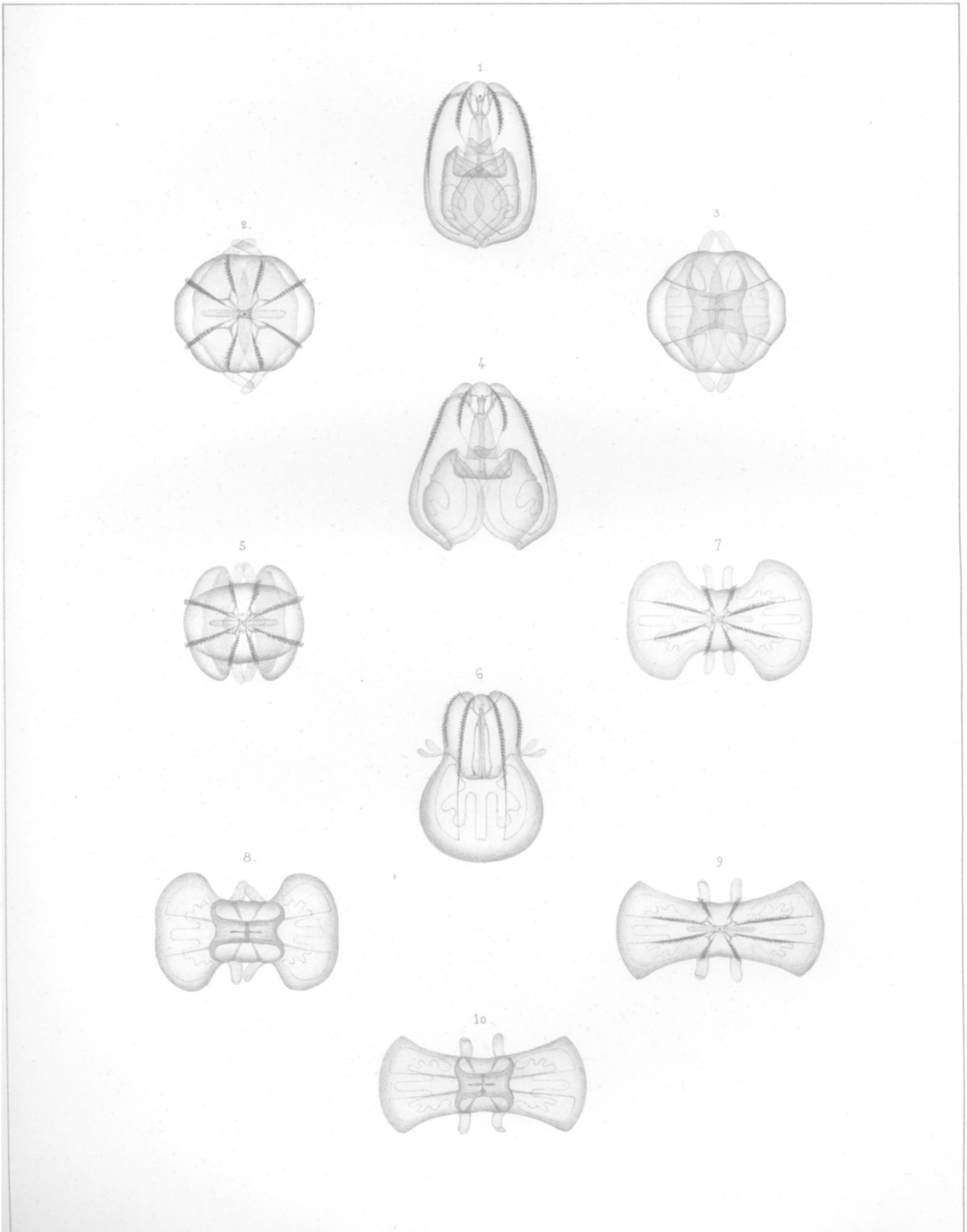
Tappan & Bradford's lith^{y}

PLEUROBRACHIA RHODODACTYLA Agass.



A. Sonrel on stone. Tappan & Bradford's lith.

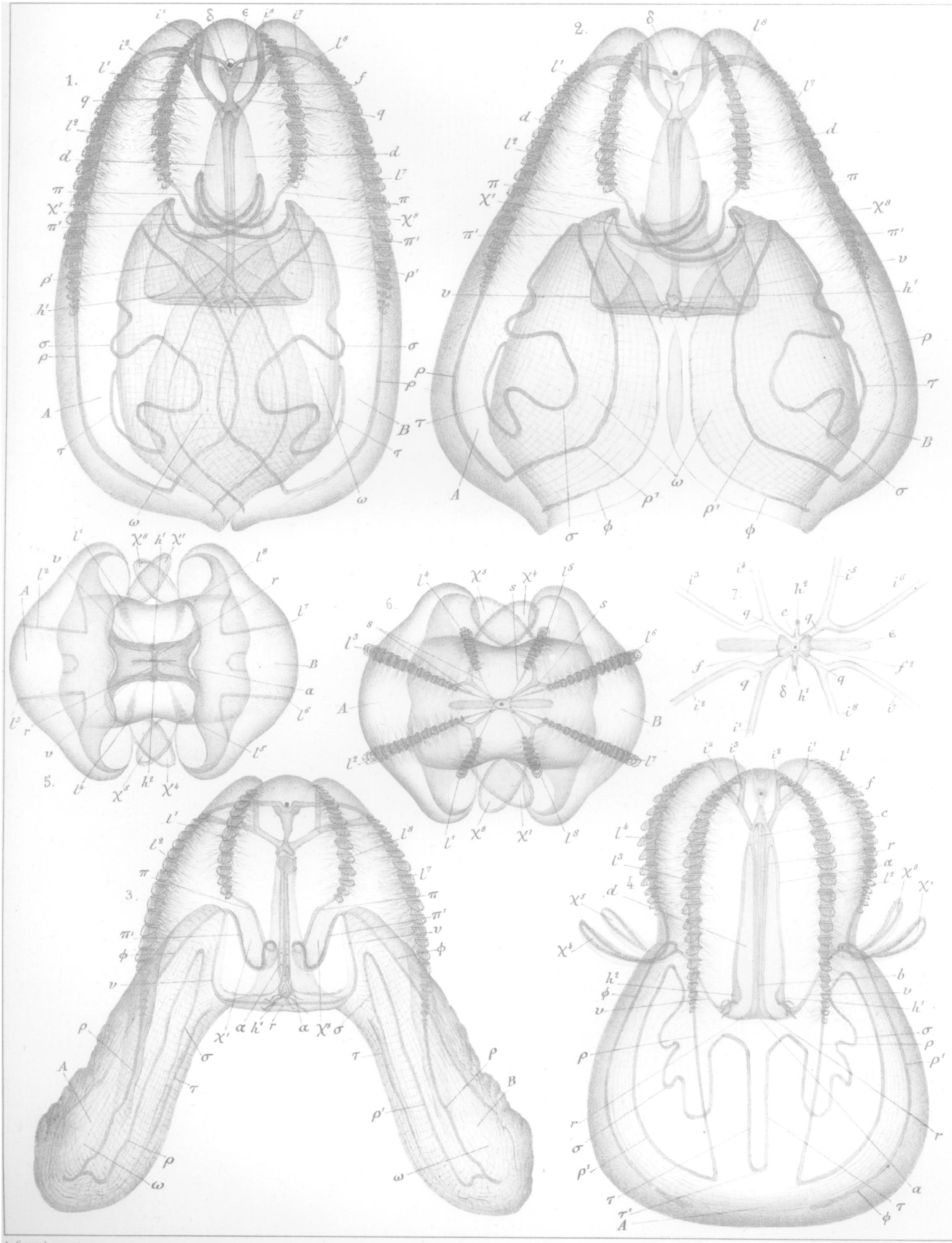
PLEUROBRACHIA RHODODACTYLA Agass.



A. Sonrel on stone

Tappan & Bradford's lith.

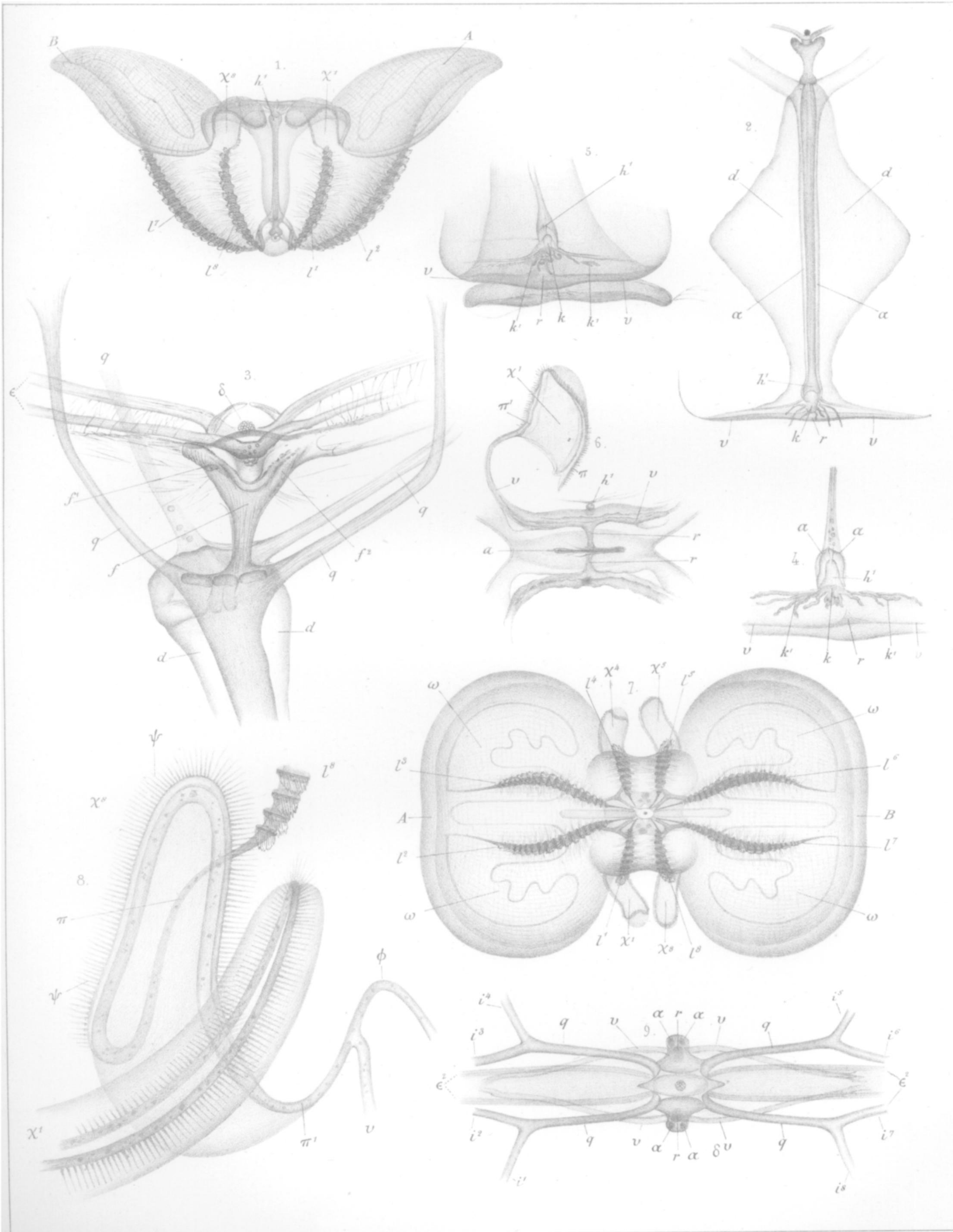
BOLINA ALATA Agass.



A. Sonrel on stone

Tappan & Bradford's lith.

BOLINA ALATA Agass.



A. Sonrel on stone.

Tappan & Bradford's lith.

BOLINA ALATA Agass.